The US Army's Center for Strategy and Force Evaluation

TECHNICAL PAPER
CAA-TP-96-1

SIMULATION ENHANCEMENTS FROM ARDENNES CAMPAIGN ANALYSIS (SEACA)

OCTOBER 1996

PREPARED BY
OPERATIONS SUPPORT DIVISION

US ARMY CONCEPTS ANALYSIS AGENCY
8120 WOODMONT AVENUE
BETHESDA, MARYLAND 20814-2797

CAA
CONCEPTS ANALYSIS AGENCY

REPORT DOCUMENTATION PAGE	*Form Approved* *OPM NO. 0704-0188*

1. AGENCY USE ONLY (Leave Blank)	2. REPORT DATE October 1996	3. REPORT TYPE AND DATES COVERED Final, Dec 95 - Oct 96

4. TITLE AND SUBTITLE Simulation Enhancements from Ardennes Campaign Analysis (SEACA)	5. FUNDING NUMBER

6. AUTHOR(S) Dr. Ralph E. Johnson	

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **US Army Concepts Analysis Agency** **8120 Woodmont Avenue** **Bethesda, MD 20814-2797**	8. PERFORMING ORGANIZATION REPORT NUMBER CAA-TP-96-1

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Director US Army Concepts Analysis Agency 8120 Woodmont, Bethesda, MD 20814-2797	10. SPONSORING/ MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILBILITY STATEMENT Approved for public release; distribution unlimited	12b. DISTRIBUTION CODE A

13. ABSTRACT (Maximum 200 words)

The Ardennes Campaign Simulation (ARCAS) Study, completed by the US Army Concepts Analysis Agency (CAA) in December 1995, suggested modifications to the Concepts Evaluation Model (CEM) and to the Stochastic CEM (STOCEM) that should render the simulations more realistic by bringing simulation results into closer agreement with historical results such as the results of the 1944 Ardennes Campaign (known as the Battle of the Bulge). The CEM is a fully automated, constructive computer model of theater-level warfare that is used extensively for Army studies of force capabilities and requirements. The objectives of this research are as follows: (1) investigate the potential enhancements to the CEM and STOCEM suggested by the ARCAS Study; (2) determine a suitable logic for such enhancements; (3) implement and test the enhancements; and (4) compare the enhanced simulation results with the results of the ARCAS Study. This report describes the implementation of the model modifications and provides results, observations, and recommendations of the research.

14. SUBJECT TERMS Simulation, validation, modeling, warfare, Ardennes Campaign	15. NUMBER OF PAGES *115*
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT UNCLASSIFIED	18. SECURITY CLASSIFICATION OF THIS PAGE UNCLASSIFIED	19. SECURITY CLASSIFICATION OF ABSTRACT UNCLASSIFIED	20. LIMITATION OF ABSTRACT UL

SIMULATION ENHANCEMENTS FROM ARDENNES CAMPAIGN ANALYSIS (SEACA)

October 1996

Prepared by

OPERATIONS SUPPORT DIVISION

US Army Concepts Analysis Agency
8120 Woodmont Avenue
Bethesda, Maryland 20814-2797

This document was prepared as part of an internal CAA project.

	SIMULATION ENHANCEMENTS FROM ARDENNES CAMPAIGN ANALYSIS (SEACA)	SUMMARY CAA-TP-96-1

THE REASON FOR PERFORMING THE STUDY is to examine how the logic of the Concepts Evaluation Model (CEM) and of the Stochastic CEM (STOCEM) can be modified to respond to the recommendations of the Ardennes Campaign Simulation (ARCAS) Study, and to learn to what extent the fidelity of STOCEM is improved by such modifications in simulating the Ardennes Campaign.

THE STUDY SPONSOR is the Director, US Army Concepts Analysis Agency (CAA).

THE STUDY OBJECTIVES are to:

(1) Investigate the potential enhancements to the CEM and STOCEM suggested by the Ardennes Campaign Analysis Study.

(2) Determine a suitable logic for such enhancements.

(3) Implement and test the enhancements.

(4) Compare the enhanced simulation results with the results of the ARCAS Study.

THE SCOPE OF THE STUDY is limited as follows:

(1) The campaign scenario used in the simulations is the 1944-45 World War II Ardennes Campaign as represented in the Ardennes Campaign Simulation Data Base (ACSDB).

(2) The model used to simulate the historical campaign is the STOCEM.

(3) Sixteen stochastic replications of STOCEM are executed for each situation. Uncertainty in STOCEM outcomes is presented by means of confidence intervals and maximum/minimum values over the 16 replications.

(4) Campaign outcome measures examined include personnel casualties, weapon system availabilities and losses, ammunition consumption, and progress of the forward edge of the battle area (FEBA).

THE BASIC APPROACH of this analysis is to:

(1) Modify the logic of STOCEM, in response to ARCAS suggestions, (a) to permit a user of STOCEM to limit by input the maximum duration of a sustained attack by a maneuver unit of each side; (b) to force maneuver units to stop at input-specified objective lines for each STOCEM sector; and (c) to represent an overrun by an attacking unit that has a large force ratio advantage in a STOCEM subsector engagement.

(2) Using the simulation inputs and STOCEM code of the ARCAS Study, modified as above, conduct STOCEM simulations, 16 replications per case.

(3) Using graphical and statistical techniques including confidence intervals, compare the results of the STOCEM with historical results and with the results of unmodified STOCEM to demonstrate the effects of the variations in STOCEM model logic and inputs.

THE PRINCIPAL FINDINGS of the work reported herein are as follows.

(1) The STOCEM modification to stop attacking forces in STOCEM from advancing beyond their objective brings the final STOCEM FEBA location into very close agreement with the recorded locations of units at the end of the Ardennes Campaign. Otherwise, most of the STOCEM outcome measures that were significantly different from history in ARCAS remain significantly different from historical results of the Ardennes Campaign after the STOCEM enhancements.

(2) Limiting the duration of attacks on both sides to 24 hours while simultaneously using breakthrough/overrun in STOCEM yields a D+8 average FEBA location close to the historical D+8 FEBA. Limiting the duration of attacks does not bring STOCEM losses of personnel nor of equipment nor ammunition consumption into significantly closer agreement with history.

(3) The implementation of breakthrough/overrun in STOCEM brings the number of captured/missing in action (CMIA) casualties significantly closer to historical results, but breakthrough/overrun in STOCEM produces STOCEM German personnel casualties significantly higher than historical casualties. Breakthrough/overrun in STOCEM yields attrition in some categories, such as artillery of both sides, that is closer to, but still significantly different from, historical results.

(4) The allocation of American and British personnel casualties among killed in action (KIA), wounded in action (WIA), CMIA, and disease and nonbattle injury (DNBI) can be brought closer to historical results of the Ardennes Campaign by increasing the DNBI rate input to STOCEM and increasing the fraction of combat casualties that are CMIA; but increasing the DNBI rate input to STOCEM has the effect of increasing total casualties so that STOCEM total casualties exceed historical results.

THE STUDY EFFORT was directed by Dr. Ralph Johnson, Operations Support Division, CAA.

COMMENTS AND SUGGESTIONS may be sent to the Director, US Army Concepts Analysis Agency, ATTN: CSCA-OS, 8120 Woodmont Avenue, Bethesda, Maryland 20814-2797.

CONTENTS

FIGURES

FIGURE   **Page**

FIGURE   **Page**

FIGURE   **Page**

SIMULATION ENHANCEMENTS FROM ARDENNES CAMPAIGN ANALYSIS (SEACA)

CHAPTER 1

EXECUTIVE SUMMARY

1-1. PROBLEM. The Ardennes Campaign Simulation (ARCAS) Study, Reference 1, completed by the US Army Concepts Analysis Agency (CAA) in December 1995, suggested modifications to the Concepts Evaluation Model (CEM) and to the Stochastic CEM (STOCEM) that should render the simulations more realistic by bringing simulation results into closer agreement with historical results such as the results of the 1944 Ardennes Campaign.

1-2. BACKGROUND

    a. In 1987, the Director, CAA, proposed that a new electronic data base describing the 1944-45 Ardennes Campaign (known as the Battle of the Bulge) be constructed for potential use in the analysis and possible validation of computer models that simulate warfare. This data base, designated the Ardennes Campaign Simulation Data Base (ACSDB), was completed under contract by Data Memory Systems, Incorporated, in December 1989. In the Ardennes Campaign German forces were opposed by American and United Kingdom (US/UK) forces.

    b. Developed at CAA, the CEM is a low-resolution, two-sided, fully automated, constructive computer model of theater-level warfare that is used extensively for Army studies of force capabilities and requirements. The CEM is one example of an extensively employed theater-level model that remained deterministic due to computer resource constraints. In recent years, however, the availability of fast computers and supercomputers has reduced execution time so much that it is feasible to conduct multiple replications of the theater-level simulations. Beginning in 1991, CAA has initiated a series of studies (References 2, 3, and 4) to explore the possibilities and performance characteristics of a stochastic simulation model of theater warfare, based on the CEM, called STOCEM. Selected findings of these studies include the following.

    (1) It is feasible to enhance the CEM with stochastic combat model processes and generate multiple replications of stochastic theater-level simulations. The cost in computer resources of executing 10 STOCEM replications is not prohibitive.

    (2) The STOCEM can be used to present results with ranges of variability and distributions of outcomes.

    (3) The differences among certain outcomes between the stochastic and deterministic CEM simulations are statistically significant.

    (4) No single stochastic process in the STOCEM is the greatest contributor to the variability observed in all of the different outcome measures of the STOCEM. Rather, a wide variety of the stochastic processes of the STOCEM are responsible for the variation in STOCEM outcome measures.

(5) For many of the outcome measures examined, the distribution of results of the STOCEM using deterministic assessment of attrition (that is, using an average combat sample) is significantly different from the distribution of results of the STOCEM using stochastic assessment (that is, using individual replications of the Combat Sample Generator, COSAGE).

c. Ref. 1 found certain major differences between STOCEM simulation results and history, including "excessively fast [forward edge of the battle area (FEBA)] movement during the last half of the campaign, excessively high antitank/mortar (AT/M) losses and American and British (US/UK) armored personnel carrier (APC) losses, excessively low artillery losses, and a much larger German ammunition tonnage expenditure" in STOCEM results as compared with ACSDB records. Ref. 1 included the following "key areas of investigation for CEM input and logic modification derived from the ARCAS STOCEM/history comparisons."

(1) Methods which moderate the CEM-calculated move rate capability in response to a "sufficiently sustained" rapid combat advance; that is, to require a "pause" to be programmed into STOCEM movement following multiple successive time periods (cycles) of continual attack activity by the same unit

(2) Reevaluation of ARCAS input German ammunition round weights and revising them as required.

(3) Modification of the STOCEM casualty partitioning computer routines to better fit the historical data on killed in action (KIA), wounded in action (WIA), captured/missing in action (CMIA), and disease/ nonbattle injuries (DNBI).

(4) Modifying STOCEM to simulate a "breakthrough" attack posture generating accelerated defender systems attrition and CMIA/DNBI, related to speed and overwhelming force advantage.

(5) Modifying STOCEM computer routines to force each STOCEM unit to stop at input-specified objective positions. (Current STOCEM only prevents further attacks after an attacker has reached or passed its objective.)

1-3. PURPOSE AND OBJECTIVES

a. **Purpose.** The purpose of this research analysis activity (RAA) is to examine how the computer routines of CEM and STOCEM can be modified to respond to the recommendations of Ref. 1 and to learn to what extent the fidelity of STOCEM is improved by such modifications in simulating the Ardennes Campaign.

b. **Objectives**

(1) Investigate the potential enhancements to the CEM and STOCEM suggested by the Ardennes Campaign Analysis Study.

(2) Determine a suitable logic for such enhancements.

(3) Implement and test the enhancements.

(4) Compare the enhanced simulation results with the results of the ARCAS Study.

1-4. SCOPE

a. The campaign scenario used in the simulations is the 1944-45 World War II (WWII) Ardennes Campaign as represented in the ACSDB.

b. As in the ARCAS Study the model used to simulate the historical campaign is the STOCEM.

c. Sixteen stochastic replications of STOCEM are executed for each situation. Uncertainty in STOCEM outcomes is presented by means of confidence intervals and maximum/minimum values over the 16 replications.

d. Campaign outcome measures examined include personnel casualties, weapon system availabilities and losses, ammunition consumption, and progress of the forward edge of the battle area (FEBA).

1-5. ASSUMPTIONS.

a. The ACSDB adequately represents the daily status of forces--equipment, personnel, ammunition--in the Ardennes Campaign of 1944-45. The inputs to the STOCEM prepared and used in ARCAS are accurate in representing the Ardennes Campaign scenario, except as noted.

b. The calculation of FEBA location defined and used in Ref. 1 provides an adequate representation of the historical FEBA, comparable to the FEBA reported by STOCEM.

c. The historical personnel casualties among line units and artillery units, stratified by casualty type, are correctly extracted from the ACSDB by the ARCAS, as reported in Ref. 1, and are directly comparable with the stratified casualties reported by STOCEM.

1-6. LIMITATIONS

a. No modifications are made to the attrition inputs to STOCEM that are obtained from the COSAGE. Inputs to STOCEM include 19 replications of COSAGE for the static posture and 16 COSAGE replications for each of the other postures.

b. Comparisons between STOCEM results and historical results are made only at theater level, rather than for individual units (regiments, brigades, divisions, corps).

c. Findings and insights do not necessarily extend to simulations other than the particular Ardennes Campaign scenario used for this study.

d. Findings regarding STOCEM do not necessarily apply to the deterministic CEM.

1-7. APPROACH

a. Examine the STOCEM simulation inputs and STOCEM computer routines used in ARCAS for errors, and correct any errors that are found.

b. Modify the computer routines of STOCEM to (1) permit a user of STOCEM to limit by input the maximum duration of a sustained attack by a maneuver unit of each side, in response to the ARCAS recommendation "to require a 'pause' to be programmed into STOCEM movement following multiple successive time periods (cycles) of continual attack activity by the same unit;" (2) to force maneuver units to stop at input-specified objective lines for each STOCEM sector, in response to an ARCAS suggestion; and (3) to represent an overrun by an attacking unit that has a large force ratio advantage in a STOCEM subsector engagement, in response to the ARCAS recommendation for a "breakthrough" combat attack posture.

c. Using the simulation inputs and STOCEM computer routines of ARCAS, modified as noted in the preceding paragraphs, conduct the following 6 sets of STOCEM simulations, 16 replications per set:

(1) A STOCEM "base case" with inputs corrected as discussed above and with the STOCEM modification to prevent forces from advancing beyond input-specified objectives, but without the new limits on duration of attacks and the new breakthrough/overrun computer routines.

(2) The maximum duration of attack by any US/UK brigade or German division limited to 24 hours--two STOCEM division cycles--without breakthrough/overrun modification of STOCEM.

(3) The maximum duration of attack by any US/UK brigade limited to 12 hours--a single STOCEM division cycle--with an 8-day limit on the duration of German attacks, without the breakthrough/overrun modification.

(4) Breakthrough/overruns whenever the attacker/defender combat worth ratio exceeds 6.0 in a STOCEM subsector, with 10 percent of the overrun unit's personnel in the subsector becoming CMIA casualties, without limits on the duration of attacks by either side.

(5) The US/UK DNBI rate input to STOCEM increased, the fraction of US/UK combat casualties that are CMIA increased, without the new limits on duration of attacks and the new breakthrough/overrun modification.

(6) Breakthrough/overruns whenever the attacker/defender combat worth ratio exceeds 6.0 in a STOCEM subsector, with 10 percent of the overrun unit's personnel in the subsector becoming CMIA casualties, with 24-hour limits on the duration of attacks by either side.

d. Using graphical and statistical techniques including confidence intervals, compare the results of the STOCEM with historical results and with the STOCEM base case, to demonstrate the effects of the variations in STOCEM model computer routines and inputs.

1-8. ESSENTIAL ELEMENTS OF ANALYSIS (EEAs)

a. What is an appropriate methodology for improvement of CEM/STOCEM?

ANSWER: Movement beyond STOCEM sector objectives is prevented by reducing the distance advanced, to the distance to the sector objective, whenever an attacking unit would advance beyond the objective in its sector. A limit on the duration of continuous attack is implemented in STOCEM as follows: the STOCEM user inputs limits on the number of consecutive (12-hour) division cycles of attack, one input for Blue brigades, another input for Red divisions; STOCEM maintains in an array the number of division cycles each unit (Blue brigade and Red division) has been attacking; this number is set to zero whenever the unit does not attack; when this number reaches the input limit for a Blue brigade or Red division, that unit is prevented from attacking, and the number of cycles attacking is set to zero. A STOCEM representation of breakthrough/overrun is implemented as follows: the STOCEM user inputs a threshold T for overrun and a fraction C of personnel that are captured/missing in an overrun; breakthrough/overrun occurs in subsector engagements when actual attacker/defender combat worth ratio, after attrition on both sides, exceeds T; when breakthrough/overrun occurs, all WIA and DNBI casualties of the overrun side in the subsector become CMIA; in addition, C times the noncasualty personnel of the overrun side in the subsector become CMIA; all damaged vehicles of the overrun side in the subsector become abandoned; and the attacker advances in the subsector at the maximum rate of advance for the terrain type, constrained by the normal STOCEM limits on length of an exposed flank.

b. How do the results of the enhanced STOCEM compare with previous STOCEM simulation results?

ANSWER: Naturally, the STOCEM modification to limit the duration of continuous attacks has the effect of reducing the cumulative distance advanced by the attacking force and of decreasing the combat losses of both sides, as compared to previous STOCEM results. Detailed comparisons are presented in Chapter 4. Conversely, the STOCEM modification to represent breakthrough/overrun has the effect of increasing the cumulative distance advanced by the attacking force and of increasing combat attrition. Detailed comparisons are presented in Chapter 5. The STOCEM modification to stop attacking forces in STOCEM from advancing beyond their objective reduces the distance advanced by counterattacking US/UK forces by an average of 10 kilometers per sector, as compared to previous STOCEM results.

c. How do the results of the enhanced STOCEM compare with Ardennes Campaign historical results?

ANSWER:

(1) The STOCEM modification to stop attacking forces in STOCEM from advancing beyond their objective brings the final STOCEM FEBA location into very close agreement with the recorded locations of units at the end of the Ardennes Campaign. By severely limiting the duration of US/UK attacks while leaving the duration of German attacks essentially unlimited, STOCEM FEBA location results during the latter periods of the simulation are brought significantly closer to historical results of the Ardennes Campaign. When both sides are limited to 24 hours of continuous attacks, the STOCEM German maximum advance falls significantly short of the historical advance. Limiting the duration of attacks on both sides to 24 hours while simultaneously using breakthrough/ overrun in STOCEM yields a D+8 average FEBA location close to the historical D+8 FEBA.

(2) Otherwise, most of the STOCEM outcome measures that were significantly different from history in the ARCAS Study remain significantly different from historical results of the Ardennes Campaign after the STOCEM enhancements. Limiting the duration of attacks does not bring STOCEM losses of personnel nor of equipment nor ammunition consumption into significantly closer agreement with history. The implementation of breakthrough/overrun in STOCEM brings the number of CMIA casualties significantly closer to historical results, but breakthrough/overrun in STOCEM produces STOCEM German personnel casualties significantly higher than historical casualties. Breakthrough/overrun in STOCEM yields attrition in some categories, such as artillery of both sides, that is closer to, but still significantly different from, historical results.

(3) The comparison of STOCEM results with history is summarized in tabular form in Appendix D.

1-9. OTHER FINDINGS AND OBSERVATIONS

a. Certain discrepancies between STOCEM results and the historical Ardennes Campaign persist before and after our modifications to STOCEM.

(1) The weight of the average German *Nebelwehrfer* rocket, 965 pounds, used as input to STOCEM in ARCAS, was found to be incorrect and was corrected to 143 pounds. The quantities of German nondivisional artillery units, used as input to STOCEM in ARCAS, were found to be overstated and were corrected. The corrected STOCEM inputs have resulted in a drastic (72 percent) reduction in German ammunition consumption from ARCAS STOCEM results. Nevertheless, the STOCEM consumption of German ammunition remains significantly higher than historical consumption after D+4.

(2) As noted in ARCAS, "STOCEM consistently overestimates KIA and WIA casualties and underestimates CMIA and DNBI casualties" (Ref. 1, pp 6-7). The allocation of US/UK personnel casualties among KIA, WIA, CMIA, and DNBI can be brought closer to historical

results of the Ardennes Campaign by increasing the DNBI rate input to STOCEM and increasing the fraction of combat casualties that are CMIA. However, increasing the DNBI rate input to STOCEM has the effect of increasing total casualties, so that STOCEM total casualties exceed historical results. Hence, the combat casualties occurring in STOCEM must be reduced, presumably in the COSAGE/Attrition Calibration (ATCAL) attrition process, if the allocation of casualties among KIA, WIA, CMIA, and DNBI, as well as total personnel casualties in STOCEM, are to agree with history.

(3) The historical record indicates negligible losses of US/UK light armor after D+12 and negligible losses of US/UK antitank/mortar weapons after D+8, but these weapons continue to suffer significant attrition throughout the campaign in STOCEM. Losses of US/UK antitank/mortars are significantly less in this STOCEM base case than in the STOCEM results reported in ARCAS.

(4) US/UK artillery losses are negligible throughout the campaign in STOCEM, but there are significant US/UK artillery losses reported in the historical record.

b. Certain elements of the historical data from the ACSDB appear suspect. In particular, the attrition of US/UK antitank/mortar weapons was negligible after D+8. Also, the amount of German ammunition consumed in the Ardennes Campaign was remarkably low. Attempting to modify STOCEM so that its results are consistent with historical anomalies such as these may lead us to STOCEM changes that are not appropriate for more typical situations.

c. For D+8, when the historical German advance reached its maximum, the average FEBA location resulting from the combined breakthrough/overrun and duration-of-attack enhancements of STOCEM agrees better with history than does any previous STOCEM simulation.

1-10. RECOMMENDATIONS

a. **Combat Attrition Samples.** It appears unlikely that close agreement can be achieved between STOCEM, using the present COSAGE combat attrition samples, and historical results, because of certain significant discrepancies between historical combat losses and the losses produced by these combat samples in STOCEM. No further comparisons of STOCEM results with history should be conducted until we have combat samples from COSAGE that are consistent with history, samples that include significant attrition of US/UK artillery, in particular. Improved combat samples might produce very different Ardennes Campaign STOCEM simulation results, obviating the need for some of the changes suggested by the ARCAS Study. Moreover, it would be unproductive to attempt to modify STOCEM computer routines to overcome flaws in the combat samples, because "better" combat samples may lead STOCEM improvements in a completely different direction. Consequently, further testing and evaluation of STOCEM improvements should begin with the development of new Ardennes combat samples in COSAGE. In developing these combat samples, the operators and quality-assurers of COSAGE must be cognizant of the ARCAS Study findings:

(1) "STOCEM may kill an excessive number of German personnel when a substantial part of the US/UK force is in attack posture. ... A reduction of an attacking force's STOCEM lethality against personnel may be appropriate."

(2) "Increases in the input (to COSAGE) vulnerability of ARCAS artillery systems may be appropriate. Even ... after catastrophic breakthrough effects are discounted, the historical losses still consistently exceed those generated by STOCEM."

(3) "STOCEM may kill an excessive number of German tanks and APCs when a substantial part of the US/UK force is in attack posture. A reduction of an attacking force's lethality against enemy tanks and APCs appears appropriate, with a higher reduction associated with a higher strength advantage (for the attacker)."

(4) "The US/UK losses for mechanized systems (APCs and AT/Ms) indicates that vulnerability and exposure of these systems was probably significantly overestimated in the weapon system lethality/vulnerability input data for COSAGE, which generates the killer-victim tables used by STOCEM to calculate attrition. Examination and revision of the AT/M system data is suggested."

(5) "The ARCAS results support the hypothesis that an attacking force that is strong enough to significantly displace an opposing force is generally more conservative than STOCEM in both the rate at which it 'kills' enemy armor and in the rate that it allows its own weapon systems to be killed."

(6) "When STOCEM applies a 'delay' posture instead of a 'defend' posture, it does so, in part, to reduce losses at a cost of increased retrograde movement. The decreased losses in delay posture must be represented in COSAGE preprocessor inputs to STOCEM."

b. Stop at Objective. The STOCEM modification to stop forces from moving beyond the objective in their sector is worthwhile and should be kept in all versions of CEM and STOCEM, to be applied in future analyses whenever final objectives can be clearly defined in each sector.

c. Breakthrough and Limits on Duration of Attacks. The modification of STOCEM described in this report captures the main effects of breakthrough/overrun, but the modeling of breakthrough/overrun could be refined considerably. The ability of a STOCEM analyst to represent breakthrough and overrun by units with sufficient superiority in a sector while in the same simulation limiting the duration of attacks by units of one or both sides is a useful improvement to our campaign simulation capability, because it allows model users to represent situations that may realistically occur in combat.

d. Input Parameters. Historical research is necessary if the enhancements to STOCEM and CEM are adopted, to determine the new input parameters of these enhancements, such as the length of time a force can continue attacking without a 12-hour break, the combat worth ratio threshold for breakthrough/overrun, and the fraction of noncasualty personnel of an overrun unit that become captured/missing.

CHAPTER 2

STUDY APPROACH AND METHODOLOGY

2-1. THE STOCHASTIC CONCEPTS EVALUATION MODEL (STOCEM)

a. The CEM, developed at CAA, is a two-sided, fully automated, constructive computer simulation of theater-level warfare that is used extensively for Army analyses of force capabilities, of operational plans, and of requirements for support force structure, ammunition by type, trained personnel, and equipment replacements. The resolution of CEM maneuver units is to brigade on the Blue side, division on the Red side. The CEM is a frequently used theater-level model that for many years remained deterministic, rather than stochastic, because of computer resource constraints.

b. In recent years, the availability of fast computers and supercomputers has reduced execution time so much that it is feasible to conduct multiple replications of the theater-level simulations. Beginning in 1991, CAA has initiated a series of studies (References 2, 3, and 4) to explore the possibilities and performance characteristics of a stochastic simulation model of theater warfare, based on the CEM, called STOCEM. The STOCEM permits a user, by input, to treat each of the following CEM processes as either deterministic or stochastic.

(1) Decision Thresholds. The friendly/enemy force ratio thresholds used in the CEM to make decisions at army/Front, corps, and division headquarters, such as mission, commitment or reconstitution of reserves, assignment of sector boundaries to subordinates, and allocation to subordinates of general support artillery and close air support. In the deterministic mode, the force ratio is compared with a threshold, T, that is input. In the stochastic mode, the force ratio is compared with a threshold, T', that is drawn from a beta distribution that is controlled by the input parameters a and b as follows.

(a) If a ≠ b, then the threshold τ is drawn from a skewed beta distribution:

$$\tau = T\,[a + (b^2 - a^2)\,RNBETA(a, b)\,/\,a]\,/\,b$$

where τ = the stochastically obtained decision threshold value,

T = the input value used as the mean of the distribution,

RNBETA(a,b) is a computer routine, controlled by parameters a and b, for drawing random numbers from a beta distribution on the interval (0, 1).

Variance(τ) = $T^2\,(b - a)^2\,/\,[ab\,(a+b+1)]$,

Range of τ is (aT / b, bT / a).

(b) If a = b, then the threshold τ is drawn from a symmetric beta distribution:

$$\tau = 2T \, RNBETA(a, b)$$

where τ = the stochastically obtained decision threshold value,

T = the input value used as the mean of the distribution,

RNBETA(a,b) is a computer routine, controlled by parameters a and b, for drawing random numbers from a beta distribution on the interval (0, 1).

Variance(τ)   = $T^2 / (2a+1)$,

Range of τ is (0, 2T)

(2) Hasty/Prepared Defense Threshold. In the deterministic mode, the recent movement of the FEBA in a sector is compared with an input threshold H to determine whether a defender in the sector fights from "prepared" or "hasty" defenses. In the stochastic mode, the FEBA movement is compared with a threshold value, H', drawn from a beta distribution controlled by the input parameters a, b, and mean H, as defined in the preceding paragraph.

(3) Combat Samples. In the deterministic mode, the combat sample used for all assessments of attrition is an average of the replications of COSAGE for the appropriate posture. In the stochastic mode, for each subsector engagement an individual replication of COSAGE for the appropriate posture is randomly selected as the combat sample to be used in assessing combat attrition. The number of replications of COSAGE to be used for each posture is input by the STOCEM user.

(4) Disposition of Losses

        (a) In a subsector engagement, the quantity of combat-damaged vehicles of a particular type that are destroyed rather than repairable; the quantity of repairable damaged vehicles that must be abandoned because of adverse FEBA movement; the quantities of combat casualties of personnel that are wounded, of wounded that require hospitalization, and of hospitalized wounded that require evacuation from theater are calculated in the deterministic mode by multiplying the losses by an input fraction P.

        (b) In the stochastic mode, the disposition of combat-damaged vehicles is treated stochastically as a binomial distribution. A random number R is drawn from the uniform distribution U(0, 1). If R exceeds the input fraction P of Blue personnel combat casualties that are wounded, then none of the Blue combat casualties in the subsector engagement are wounded; if R <= P, then all the Blue combat casualties in the engagement are wounded. The other disposition decisions for personnel casualties and for damaged vehicles--tanks, light armor, helicopters, and artillery--are made stochastically the same way. A random draw is generated from a uniform distribution U(0,1). The randomly drawn number, R, is then compared to the input probability, P, of permanent loss, "K-kill," given combat damage. If R is greater than P, the vehicles damaged are classified as repairable; otherwise, they are catastrophically destroyed. The same technique is applied to determine stochastically whether repairable damaged vehicles are recovered or abandoned because of an advancing enemy, except that the probability, P, of abandonment depends on the rate of FEBA displacement. In the stochastic mode, the STOCEM

disposes of one damaged vehicle (or fraction of a vehicle) at a time, using a separate random draw from the uniform distribution for each individual vehicle, or fraction of a vehicle.

(5) FEBA Movement. The STOCEM provides users the option of stochastic modeling of displacement of the FEBA for each subsector engagement.

(a) In the deterministic mode, the attacker's rate of advance in an engagement is calculated by interpolation on an input table based on terrain type, posture, and a factor called Defender's Advantage that is derived from the fractional exchange ratio in the engagement. (Reference 5, pp 1-165) as follows:

$$\text{Defender's Advantage} = 0.5 \, log_e \{[1 - (A_r / A_i)^2] / [1 - (D_r / D_i)^2]\}$$

where A_r= attacker's combat worth remaining after the engagement,

A_i= attacker's combat worth at the start of the engagement,

D_r= defender's combat worth remaining after the engagement,

D_i= defender's combat worth at the start of the engagement.

(b) In the stochastic mode, a cumulative frequency function F for the five movement rate class intervals (very fast, fast, moderate, slow, very slow) is constructed as a function of terrain type, posture, and Defender's Advantage, using the findings of R. Helmbold (Reference 6). For a particular engagement, the Defender's Advantage is calculated, and a random number R is drawn from the uniform distribution U(0, 1). The inverse of F, $F^{-1}(R)$, yields a movement rate class, and the outcome movement rate is randomly selected using a uniform distribution within the boundaries of the selected movement rate class interval. Figure 2-1 depicts how the probabilities of the five movement rate classes are related to the value of Defender's Advantage for the engagement, derived from historical battles. In Figure 2-1, the movement rate classes for a given value of Defender's Advantage have the probabilities shown by the vertical distances between the curves above that value.
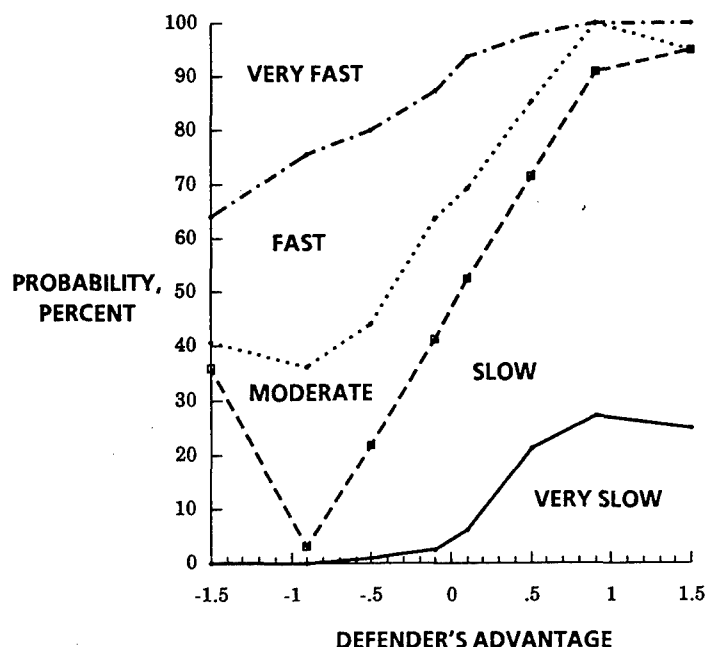
Figure 2-1. Probability of Movement Rate Class vs Defender's Advantage

2-2. TASKS

a. Our methodology begins with the establishment of a base case of the campaign, executed using the STOCEM. We obtained a full set of input data for the December 1944 Ardennes Campaign, as used in ARCAS.

b. One of the findings of ARCAS was that consumption of German ammunition in STOCEM was nearly 10 times the quantity recorded in the ACSDB. So we examined the STOCEM inputs that significantly affect the quantity of German ammunition consumption and found two key inputs that required correction: (1) the average weight of the *Nebelwehrfer* rocket, and (2) the quantity of German nondivisional artillery and rocket units that enter the campaign after 16 December 1944.

c. The STOCEM was modified, as recommended in ARCAS, to prevent attacking forces from advancing beyond the input objectives in their sector, rather than merely forcing units to cease attacking when they have crossed the objective line. The only possible effect of this change on STOCEM results is a change in the final location of the STOCEM FEBA. So this modification is included in the STOCEM base simulation for the analysis reported here.

d. Using the STOCEM enhanced as in paragraph 2-2c above, with all available processes in the stochastic mode and the input data of ARCAS, except for the corrections noted in paragraph 2-2b above, we executed 16 replications of the STOCEM. The stochastic assessment of combat attrition was modeled in the STOCEM by drawing for each engagement from the individual

replications of COSAGE for the appropriate posture. To make the STOCEM inputs as consistent as possible with those of the deterministic CEM for these STOCEM simulations, the mean value of the distribution of each of the stochastic processes of the STOCEM was set to the input value that was used in the deterministic CEM. The standard deviation was set by input at 1/10 of that mean value, for the commanders' decision threshold and hasty/prepared defense decision processes.

e. Modifications to STOCEM were designed and implemented to permit the STOCEM user to limit the number of consecutive (12-hour) combat cycles that a Blue brigade or Red division can attack. The user can select different limits for Red and Blue--for example, 36 hours for Red and 24 hours for Blue. This was implemented by means of an array containing, for each Blue brigade and each Red division, a counter of the number of consecutive 12-hour cycles that the unit has attacked. When a unit ceases attacking, its counter is reset to zero. When the counter for a Blue brigade reaches the input limit for the Blue side, the brigade is prevented from attacking in the next 12-hour cycle, and the counter is reset to zero for that brigade. Likewise, when the counter for a Red division reaches the input limit for Red, the division is prevented from attacking in the next 12-hour cycle.

f. Modifications to STOCEM were designed and implemented to permit the representation of breakthrough/overrun whenever the attacking force in a STOCEM subsector achieves an overwhelming advantage in combat worth ratio. User inputs to STOCEM establish the attacker/defender force ratio threshold above which breakthrough occurs and specify the fraction of the defending unit's personnel in the subsector that become captured/missing when the unit is overrun. A consequence of a breakthrough/overrun is that all repairable damaged vehicles in the unit that is overrun in the subsector are abandoned and, therefore, permanently lost.

g. Using the simulation inputs and STOCEM computer routines as described in paragraph 2-2d above, we executed the following 5 STOCEM variations, 16 replications per variation:

(1) The maximum duration of attack by any US/UK brigade or German division limited to 24 hours--two STOCEM division cycles--without breakthrough/overrun logic.

(2) The maximum duration of attack by any US/UK brigade limited to 12 hours--a single STOCEM division cycle--with an 8-day limit on the duration of German attacks, without breakthrough/overrun logic.

(3) Breakthrough/overruns whenever the attacker/defender combat worth ratio exceeds 6.0 in a STOCEM subsector, with 10 percent of the overrun unit's personnel in the subsector becoming CMIA casualties, without limits on the duration of attacks by either side.

(4) The US/UK DNBI rate input to STOCEM increased, the fraction of US/UK combat casualties that are CMIA increased, without the new limits on duration of attacks and the new breakthrough/overrun logic.

(5) Breakthrough/overruns whenever the attacker/defender combat worth ratio exceeds 6.0 in a STOCEM subsector, with 10 percent of the overrun unit's personnel in the subsector becoming CMIA casualties, with 24-hour limits on the duration of attacks by either side.

h. The campaign outcomes of the STOCEM replications are compared by means of graphic displays of the selected outcome measures of effectiveness (MOE) that consist of plots of confidence intervals about the mean, based on the 16 values of an outcome measure obtained from the STOCEM replications for each 2-day or 4-day cycle, as follows.

$$\text{Confidence limit} = \overline{X} \pm s \sqrt{10} / \sqrt{16}$$

where:

$\overline{X}$ = the sample mean;

s = the sample standard deviation:

$$s^2 = \sum_i (X_i - \overline{X})^2 / 15.$$

If the distribution of outcomes from the replications of STOCEM satisfies the normality conditions of the Student/Fisher t-statistic, then these displays depict confidence intervals of more than 99 percent about the mean of the distributions. However, Student/Fisher's t-statistic is not necessarily applicable, because the normality of the population of STOCEM outcomes for each outcome measure has not been established. For more statistical rigor, Chebyshev's Inequality can be applied to prove that the above confidence limits provide approximate confidence intervals of at least 90 percent about the mean of the distribution, without any assumption about the shape of the distribution, as demonstrated in Ref. 1, page 2-15.

2-3. OUTCOME MEASURES. The campaign simulation outcome MOEs used in our analysis were chosen to focus on those outcomes that are relevant to issues raised in ARCAS. The selected MOEs include measures of FEBA movement, attrition, and ammunition expenditures, in display formats that are readily comparable to the results of ARCAS, Reference 1. The following specific campaign outcome measures, available at 4-day intervals, are included in the analysis.

a. Map displays, produced by means of the Terrain Evaluation Module (TEM), that show the location of the average FEBA obtained from a set of STOCEM replications for a particular day of the campaign.

b. Cumulative Blue (US and Allied) personnel permanent casualties (dead, captured, missing, or evacuated from theater).

c. Cumulative permanent losses of Blue tanks. Permanent losses include repairable damaged vehicles that are abandoned because of a rapidly advancing enemy.

d. Cumulative permanent losses of Red (German) tanks.

e. Cumulative permanent losses of Blue artillery weapons.

f. Cumulative permanent losses of Red artillery weapons.

g. Cumulative permanent losses of Blue light armor weapons.

h. Cumulative permanent losses of Red light armor weapons.

i. Cumulative permanent losses of Blue antitank/mortar weapons.

j. Cumulative permanent losses of Red antitank/mortar weapons.

k. Cumulative Blue ammunition consumed (tons).

l. Cumulative Red ammunition consumed (tons).

m. Fraction of cumulative Blue personnel losses that are killed in action.

n. Fraction of cumulative Blue personnel losses that are wounded in action.

o. Fraction of cumulative Blue personnel losses that are captured/missing in action.

p. Fraction of cumulative Blue personnel losses that are disease or nonbattle injuries.

2-4. ORGANIZATION OF REPORT. Chapter 3 shows the STOCEM base case and compares it with the results of the historical Ardennes Campaign. Chapter 4 contains the results of the first and second variations listed in paragraph 2-2g above. These variations test the effect of limiting the duration of attacks by the maneuver forces of each side. Chapter 5 provides the results of testing the breakthrough/overrun modification of STOCEM, which is the third variation listed in paragraph 2-2g. Chapter 6 has the results of varying the inputs that affect the allocation of US/UK personnel casualties among KIA, WIA, CMIA, and DNBI, the fourth variation listed above. Chapter 7 contains the results of the fifth variation above, which combines the effects of the STOCEM modifications to limit the duration of attacks and to permit breakthrough/overruns.

CHAPTER 3

STOCEM BASE CASE

3-1. SIMULATION CHARACTERISTICS. The STOCEM base simulation whose results are presented in this chapter differs from the primary STOCEM simulation of ARCAS in the following respects.

a. STOCEM was modified to stop advancing maneuver forces at the input-specified objective line for their sector. The STOCEM used in ARCAS prevented further attacks whenever a maneuver unit had crossed its objective line.

b. The schedule of arriving nondivisional German artillery units was corrected in the STOCEM inputs. The net effect of this correction is to reduce the quantity of German artillery weapons, ammunition, and personnel, especially in the later stages of the STOCEM campaign.

c. The input weight of the average German rocket was corrected, reducing the rocket's weight by a factor of more than 6. This correction allows German artillery to fire more rockets and other rounds before exhausting the available ammunition.

d. A coding error in STOCEM was corrected which had the effect in ARCAS of allowing German general support artillery to fire more ammunition than was available.

3-2. FEBA LOCATIONS

a. Figure 3-1 displays over a map background the mean (dashed line), maximum, and minimum (white lines) FEBA locations at D+8 of the 16 replications of the STOCEM base case. Also shown in Figure 3-1 is the historical location of the FEBA (solid dark line), as calculated in ARCAS. (The circles indicate selected towns and cities as points of reference.) The gap in the FEBA for each of the STOCEM outcomes represents a boundary between armies in STOCEM that was implemented in ARCAS to ensure that forces in STOCEM stayed in the same general sectors as in the historical Ardennes Campaign.

b. Neither the maximum nor minimum FEBA represents an individual replication of STOCEM. Rather, the maximum FEBA shows the maximum German advance at D+8, *by sector*, of the 16 STOCEM replications; so it is a composite of the STOCEM replications. That is, the maximum advance in a northern sector might occur in a different STOCEM replication from the maximum advance in a southern sector of the campaign.

c. Figure 3-1 shows reasonably good agreement between STOCEM base case results and historical outcomes at D+8. In particular, the historical FEBA lies generally within the envelope of STOCEM replications; and the STOCEM average location of the deepest German penetration is very close to the historical "bulge," in the same sector of the theater, southeast of the city of Namur. In fact, the point of deepest German penetration of the STOCEM average shown here is slightly closer to the historical location than is the STOCEM average shown in Figure 3-10 of Reference 1. We see in Figure 3-1 that the deepest German advance is less in the STOCEM base

case average than in the historical FEBA calculated by ARCAS. We observe that considerable terrain lies between the maximum and minimum STOCEM FEBA locations, especially in the sectors of deepest German penetration. Hence, there is significant uncertainty about the FEBA location estimated by STOCEM for D+8.

Figure 3-1. STOCEM Base Case D+8 FEBA Location and Historical D+8 FEBA

d. Figure 3-2 depicts, in the same format as Figure 3-1, the STOCEM and historical FEBA locations at D+20. On average, the US/UK forces are more aggressive and successful at retaking terrain in STOCEM than in the historical Ardennes Campaign. This is consistent with the ARCAS finding, "After D+16, the counterattacking US/UK force in STOCEM makes the Germans retreat at a considerably more rapid rate than occurred historically" (Ref. 1, p 3-10). Again the great distance between the STOCEM maximum and minimum FEBA locations indicates the high uncertainty about the FEBA location estimated by STOCEM.

Figure 3-2. STOCEM Base Case D+20 FEBA Location and Historical D+20 FEBA

3-3. EQUIPMENT LOSSES

a. Figures 3-3 to 3-6 show cumulative permanent losses of US/UK tanks, light armor, antitank/mortar weapons, and artillery, respectively. Permanent losses include any repairable damaged vehicles that are abandoned because of a rapidly advancing enemy. STOCEM results are reported at 4-day intervals. In each chart, the solid lines show the minimum and maximum of the 16 STOCEM replications, the dashed lines show the upper and lower limits of the STOCEM

confidence intervals, the lightly shaded bar shows the mean of the STOCEM replications, and the dark-shaded bar the historical outcome. The confidence intervals displayed in these figures are defined as in ARCAS (Ref. 1, p 2-14):

$$\text{Confidence limits} = \overline{X} \pm s \sqrt{10} / 4$$

where $\overline{X}$ is the sample mean and s is the sample standard deviation:

$$s^2 = \sum_i (X_i - \overline{X})^2 / 15.$$

If the distribution of outcomes from the replications of STOCEM satisfies the normality conditions of the Student/Fisher t-statistic, then these displays depict confidence intervals of more than 99 percent about the mean of the distributions. However, Student/Fisher's t-statistic is not necessarily applicable, because the normality of the population of STOCEM outcomes for each outcome measure has not been established. For more statistical rigor, Chebyshev's Inequality can be applied to prove that the above approximate confidence limits provide at least 90 percent confidence intervals about the mean of the distribution, without any assumption about the shape of the distribution, as demonstrated in Ref. 1, p 2-15.
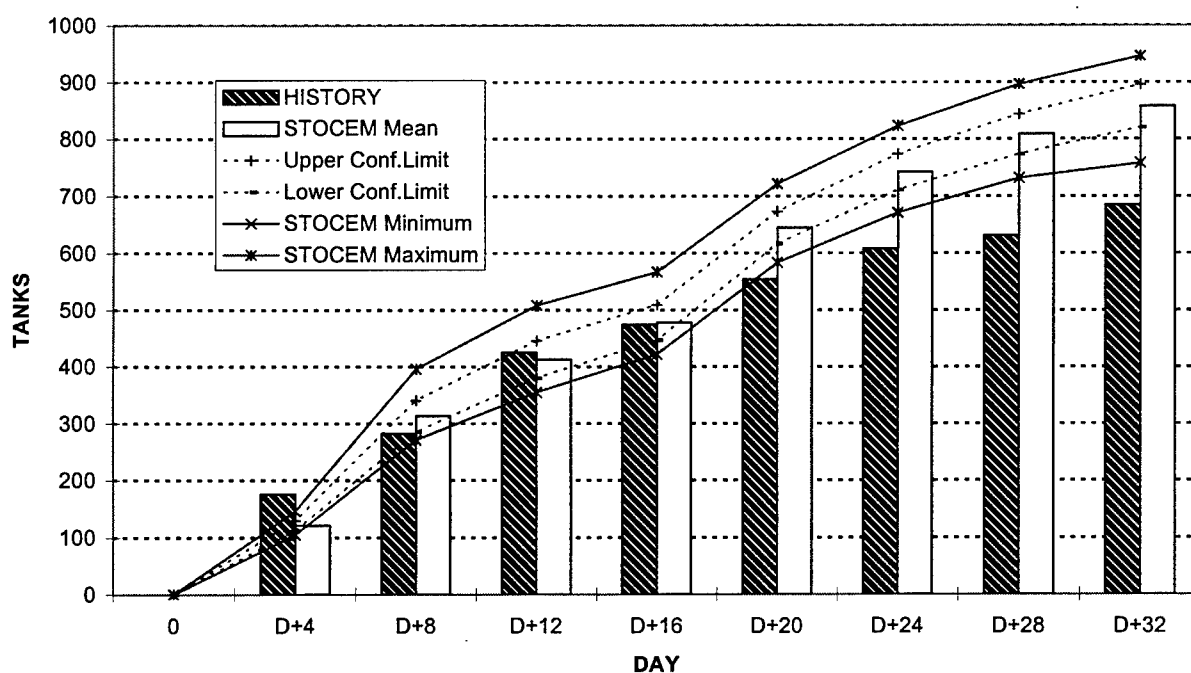

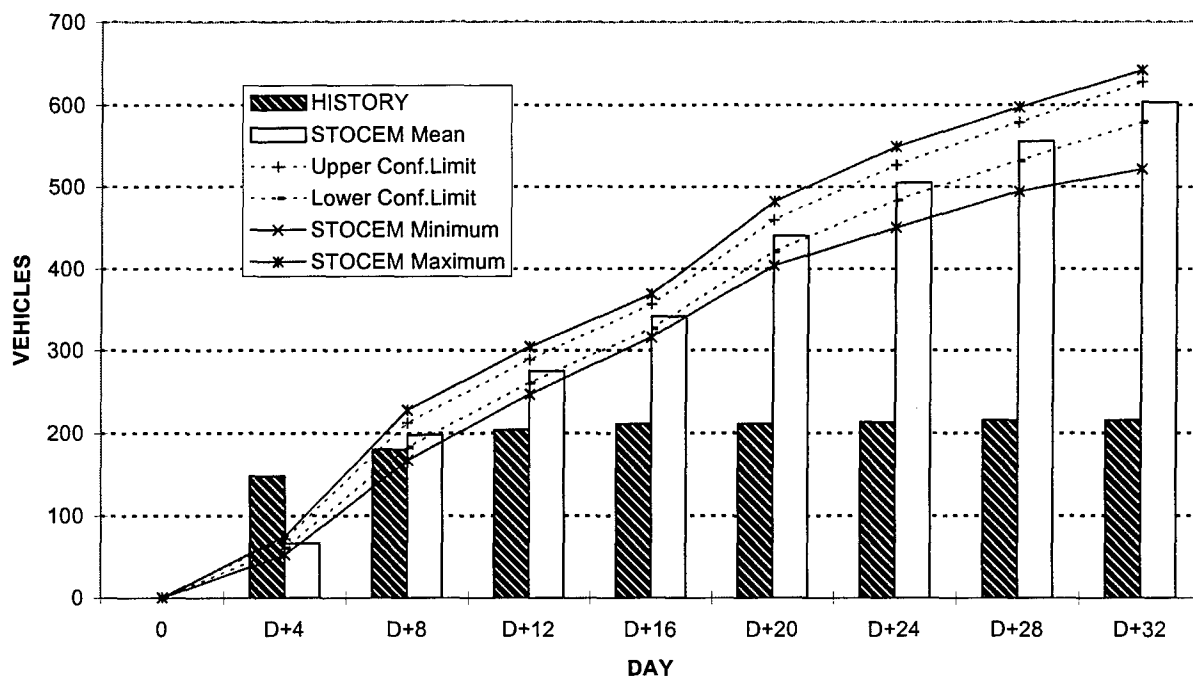**Figure 3-3. Cumulative Permanent Losses of US/UK Tanks**

Figure 3-4. Cumulative Permanent Losses of US/UK Light Armor
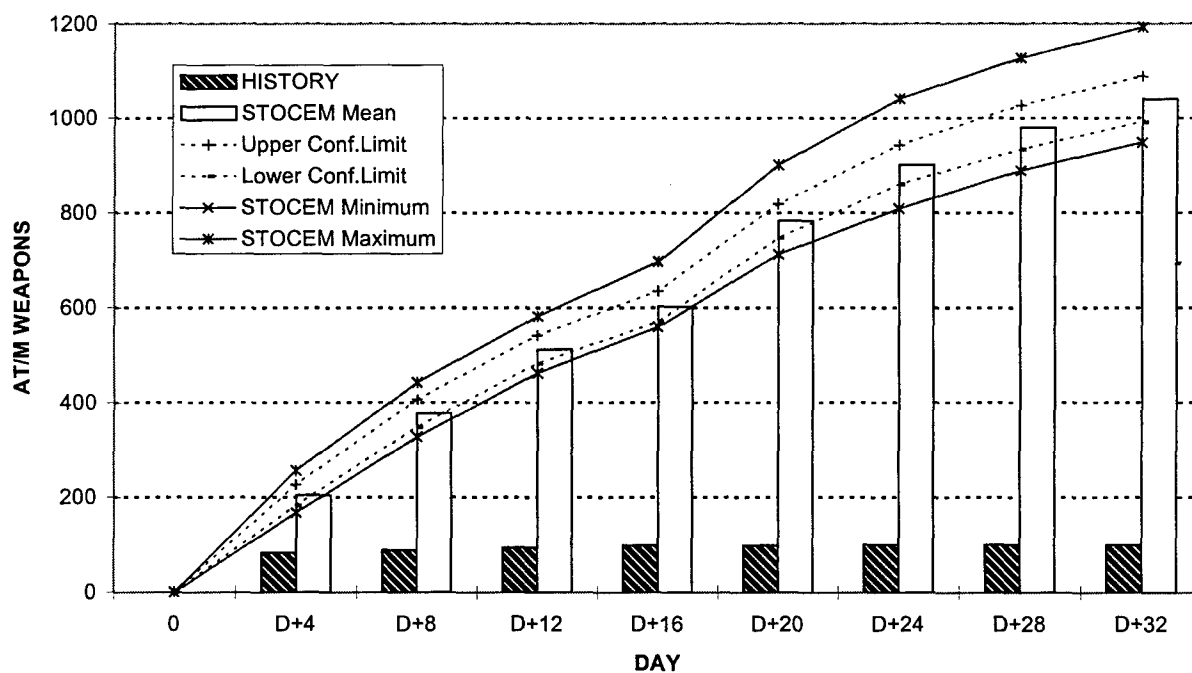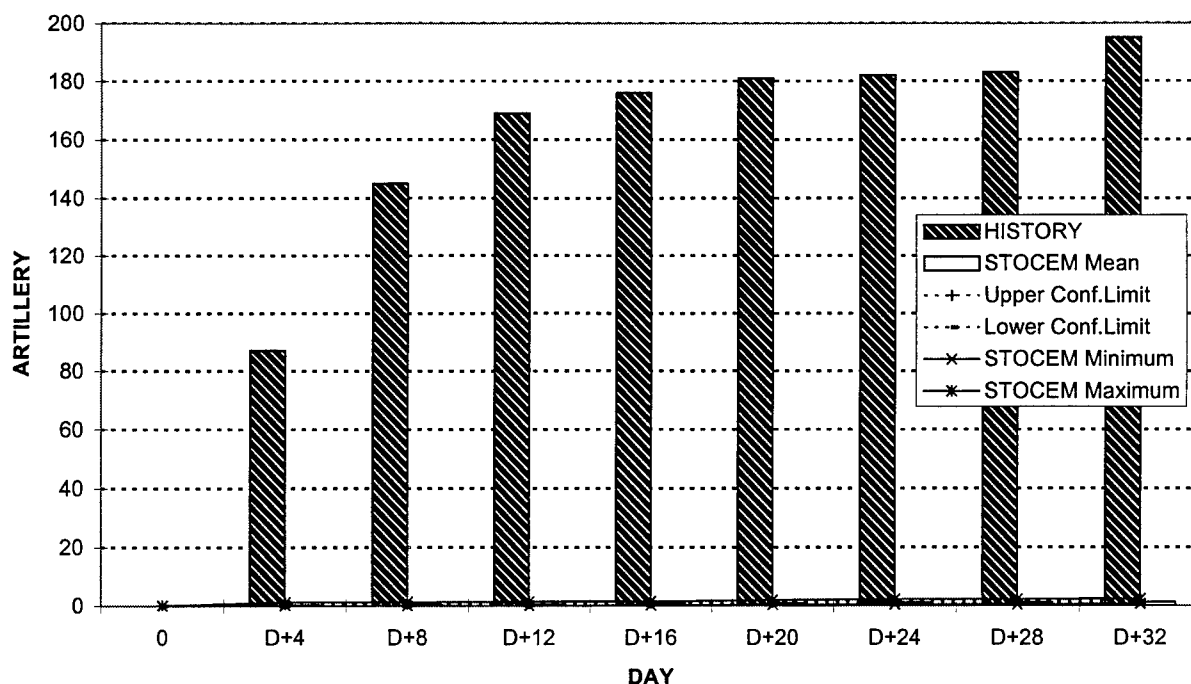

Figure 3-5. Cumulative Permanent Losses of US/UK Antitank/Mortars

Figure 3-6. Cumulative Permanent Losses of US/UK Artillery

b. Figure 3-3 shows the cumulative permanent losses of US/UK tanks, which are entirely consistent with the results reported in ARCAS. That is, STOCEM permanent tank losses are close to historical losses from D+5 through D+16, and "historical losses are proportionately higher than STOCEM losses in the first 4 days of the campaign, while they are noticeably less than STOCEM's in the latter half of the campaign" (Ref. 1, p 5-2).

c. Figures 3-4, 3-5, and 3-6 also show STOCEM base case results that are very similar to the STOCEM results of ARCAS (Ref. 1, Figures 5-5, 5-9, and 5-13). In particular, the historical record indicates negligible losses of light armor after D+12 and negligible losses of antitank/mortar weapons after D+8, but these weapons continue to suffer significant attrition throughout the campaign in STOCEM. The STOCEM modification to limit the duration of sustained attacks was expected to reduce the difference between STOCEM and historical attrition in the second half of the campaign. Also, US/UK artillery losses are negligible throughout the campaign in STOCEM, but there are significant US/UK artillery losses reported in the historical record. Losses of US/UK antitank/mortars are significantly less in this STOCEM base case than in the STOCEM results reported in ARCAS (Ref. 1, Figure 5-9), presumably due to the smaller quantities of German nondivisional artillery in the present corrected STOCEM inputs.

d. Figures 3-7 and 3-8 show the quantities of antitank/mortar weapons and artillery available for use in the combat units after attrition, repairs, and replacements. The difference between STOCEM and historical records does not appear very large when viewed in this context. The losses of Blue artillery are so small in STOCEM that the STOCEM confidence limits, mean, minimum, and maximum onhand appear identical in Figure 3-8.
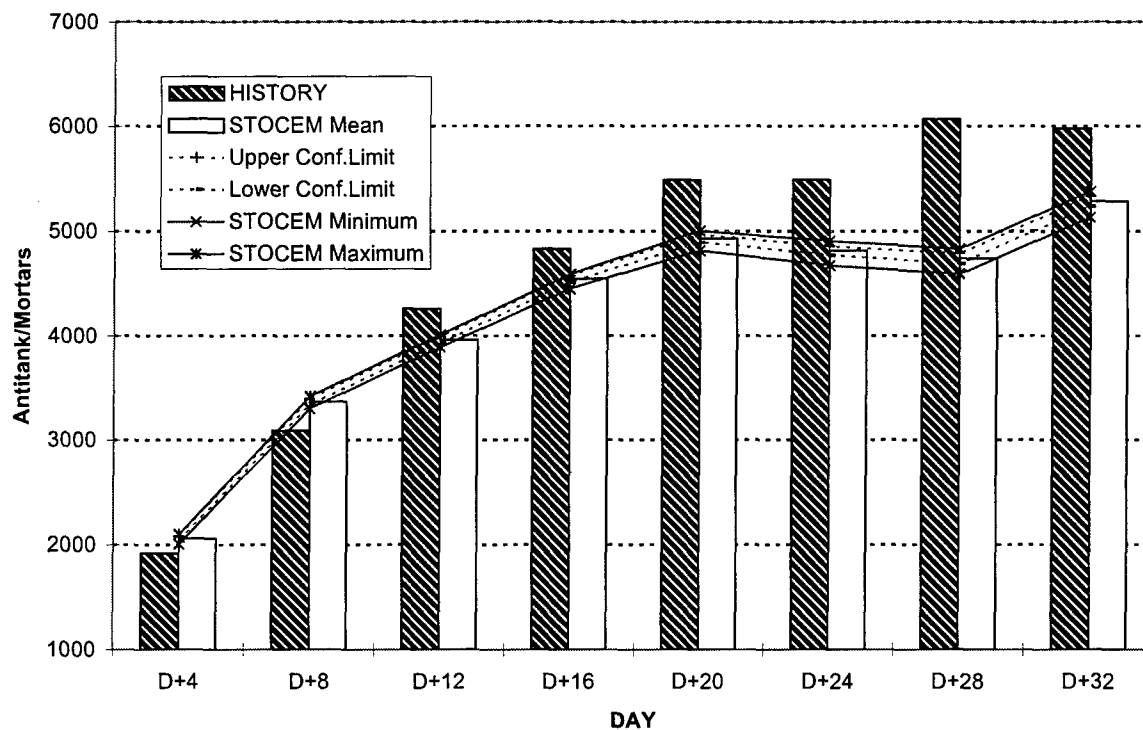
Figure 3-7. US/UK Antitank/Mortars Operational
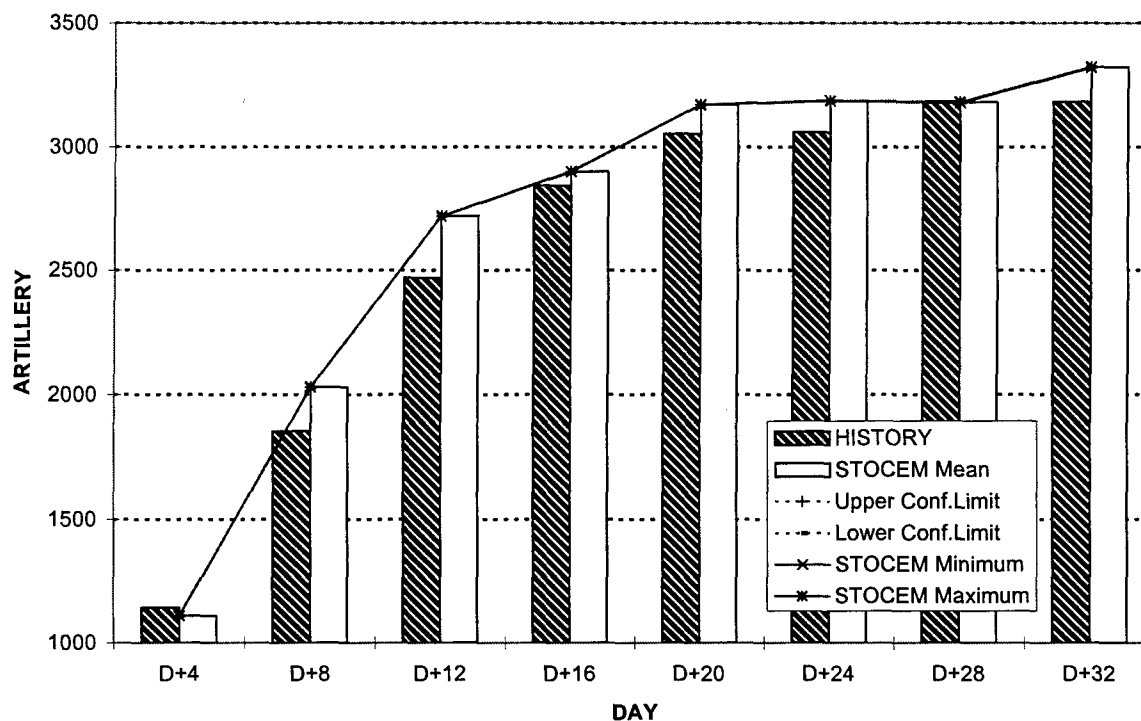
Figure 3-8. US/UK Artillery Operational

e. Figures 3-9, 3-10, 3-11, and 3-12 show the STOCEM base case cumulative permanent losses of German tanks, light armor, antitank/mortars, and artillery, respectively. Again the results of our STOCEM base case are quite similar to the STOCEM results reported in ARCAS (Ref. 1, Figures 5-3, 5-7, 5-11, and 5-15). However, the present STOCEM losses of German tanks, light armor, and antitank/mortars after D+16 are significantly greater than the STOCEM losses reported in ARCAS, presumably due to the greater quantities of surviving US/UK antitank/mortars in the present STOCEM results, as noted above.
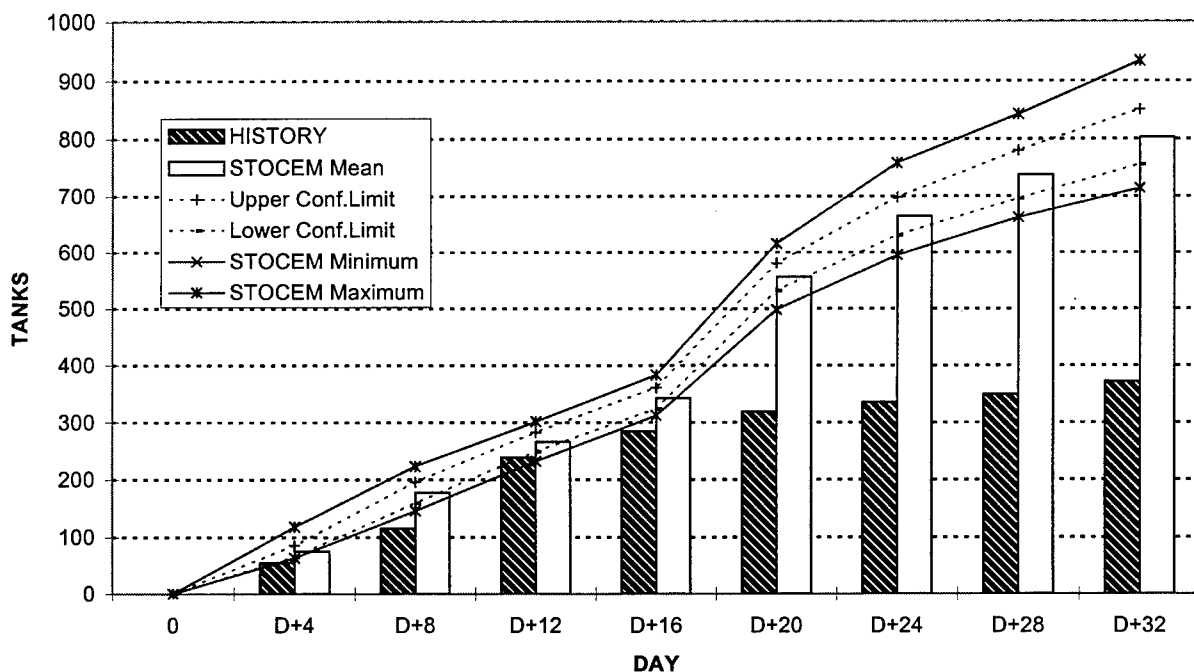
Figure 3-9. Cumulative Permanent Losses of German Tanks
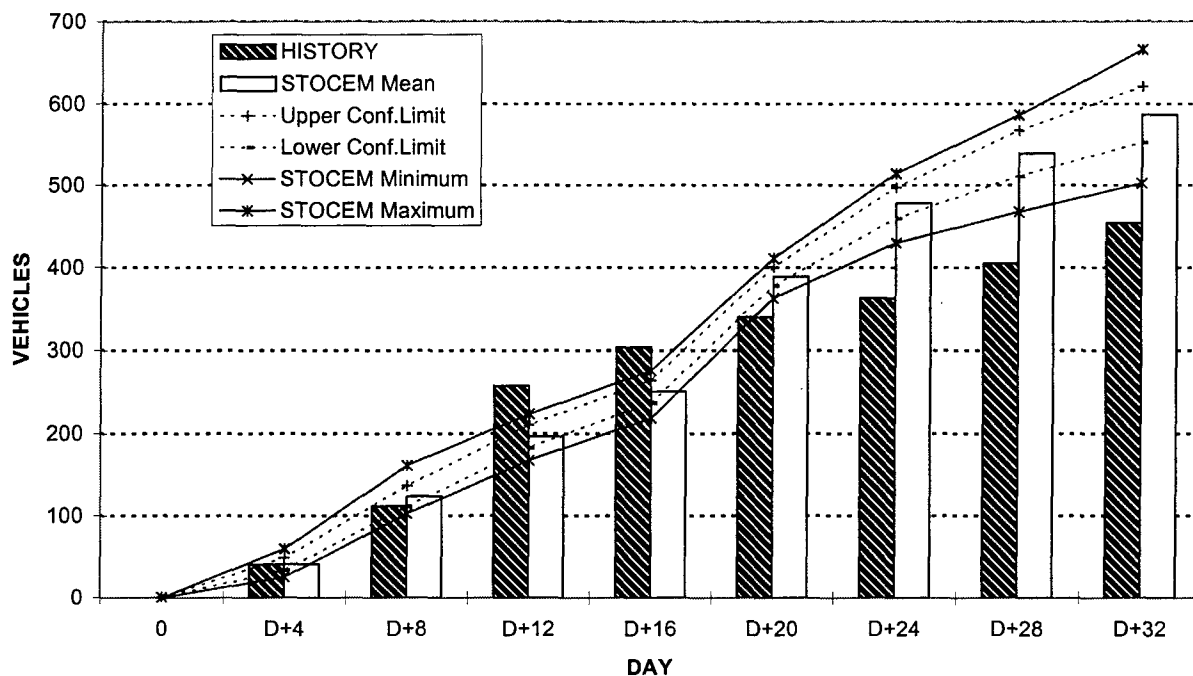
Figure 3-10. Cumulative Permanent Losses of German Light Armor
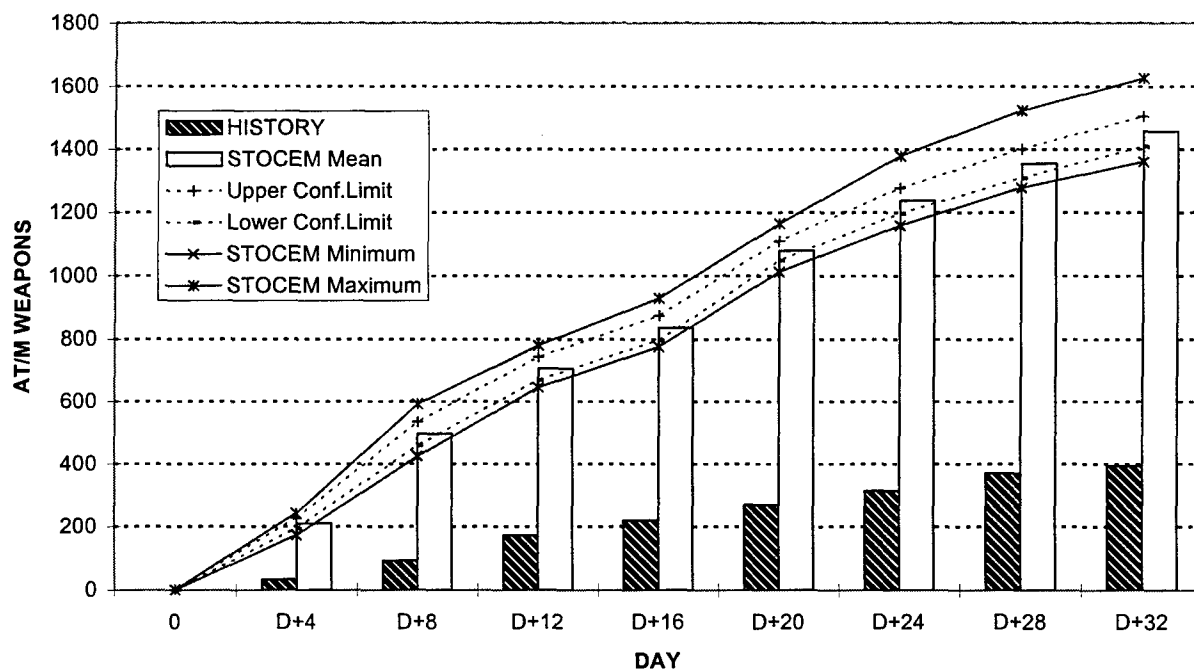
Figure 3-11. Cumulative Permanent Losses of German Antitank/Mortars
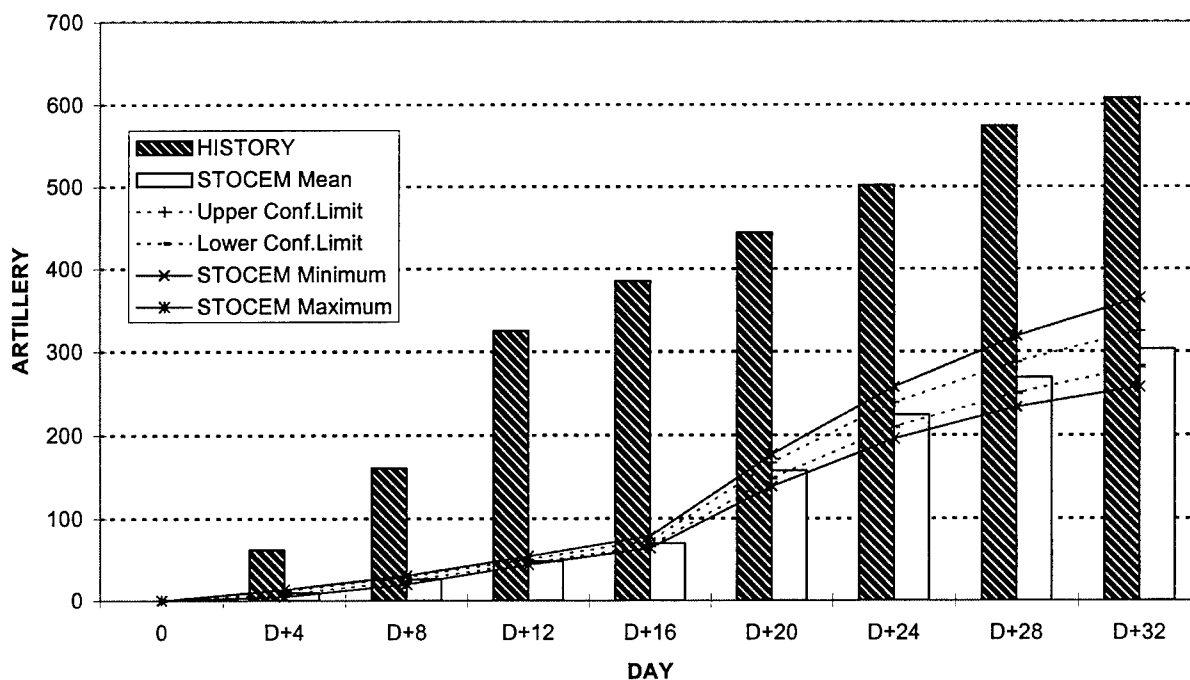
Figure 3-12. Cumulative Permanent Losses of German Artillery

f. Figures 3-11 and 3-12 show a significant discrepancy between historical attrition of German weapons and the permanent losses estimated by STOCEM. To provide an operational context, Figures 3-13 and 3-14 display the operational quantities of antitank/mortars and artillery, respectively. Operational quantities are numbers of weapons onhand in combat units, the net result of combat losses, breakdowns, repairs (for artillery, but antitank/mortars are not repaired in STOCEM), and replacements. The differences between STOCEM and history appear less significant when viewed from the perspective of operational quantities.
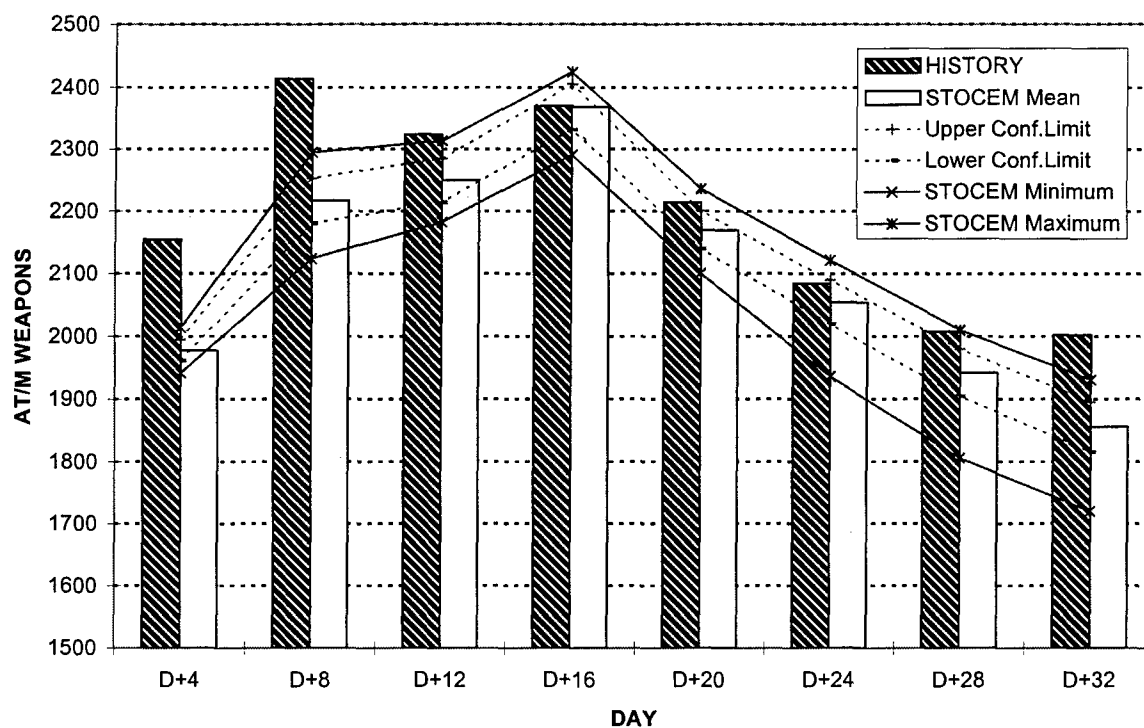
Figure 3-13. Operational German Antitank/Mortars
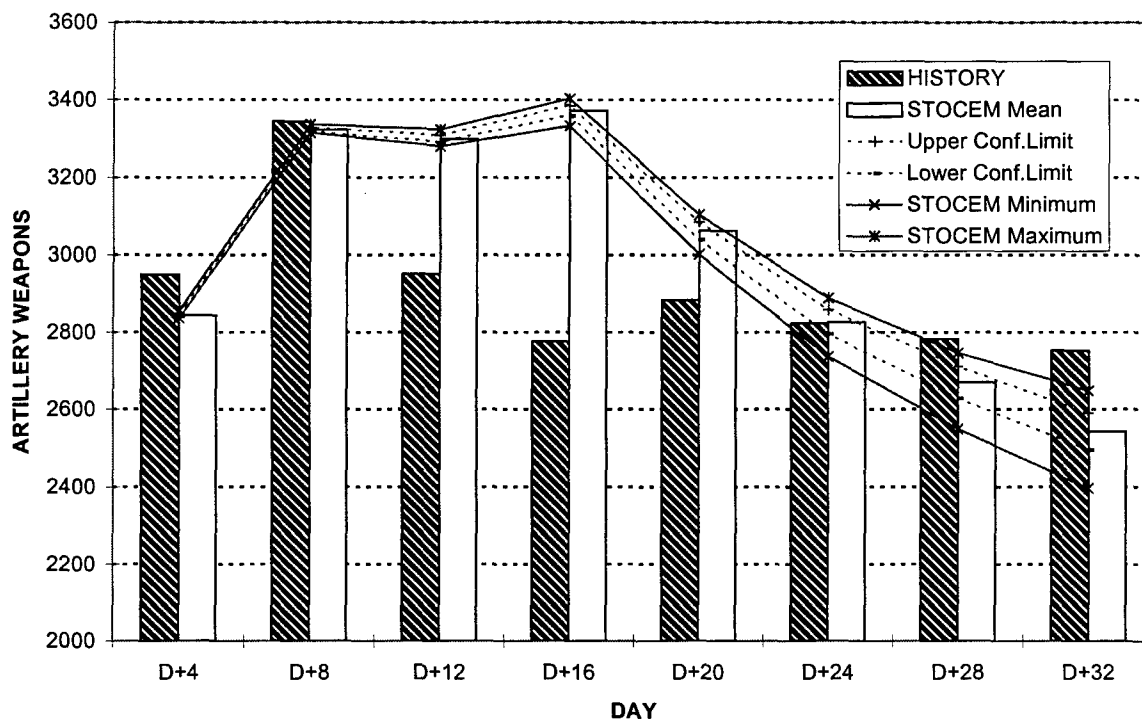
Figure 3-14. Operational German Artillery

3-4. AMMUNITION CONSUMPTION

a. Figure 3-15 shows the cumulative consumption of US/UK ammunition, in tons. By comparison with Figure 4-1 of Reference 1, it is evident that consumption of US/UK ammunition in the present STOCEM base case is slightly higher after D+16 than the STOCEM results of ARCAS. Thus, the present STOCEM base case agrees better with historical ammunition consumption than does the STOCEM simulation reported in ARCAS, apparently due to the increased quantities of surviving US/UK antitank/mortars in the present STOCEM base case, as noted above.
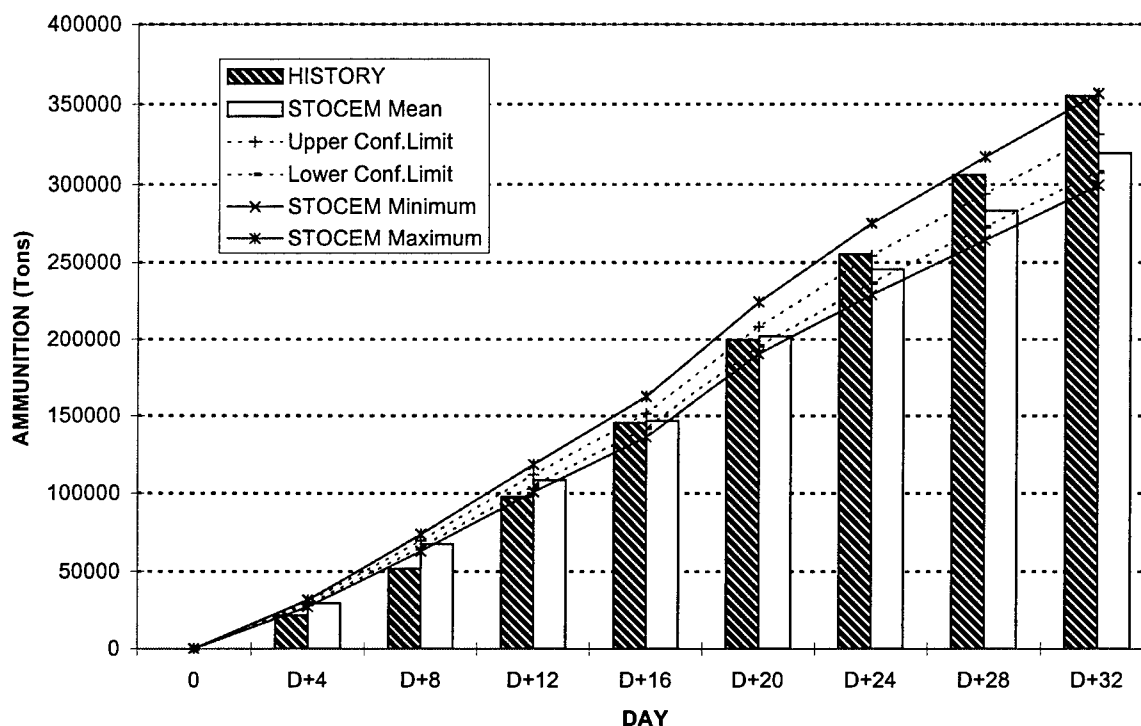
Figure 3-15. Cumulative Consumption of US/UK Ammunition (tons)

b. Figure 3-16 shows the cumulative consumption of German ammunition, in tons. The corrected STOCEM inputs have resulted in a drastic (72 percent) reduction in German ammunition consumption from ARCAS STOCEM results (Ref. 1, Figure 4-3). Nevertheless, the STOCEM consumption of German ammunition remains significantly higher than historical consumption, after D+4. If the historical records are accurate, the consumption of German ammunition in the Ardennes Campaign was remarkably low--less than 37,000 tons by D+12, for example, with some 3,000 German artillery tubes and rocket launchers in the campaign.
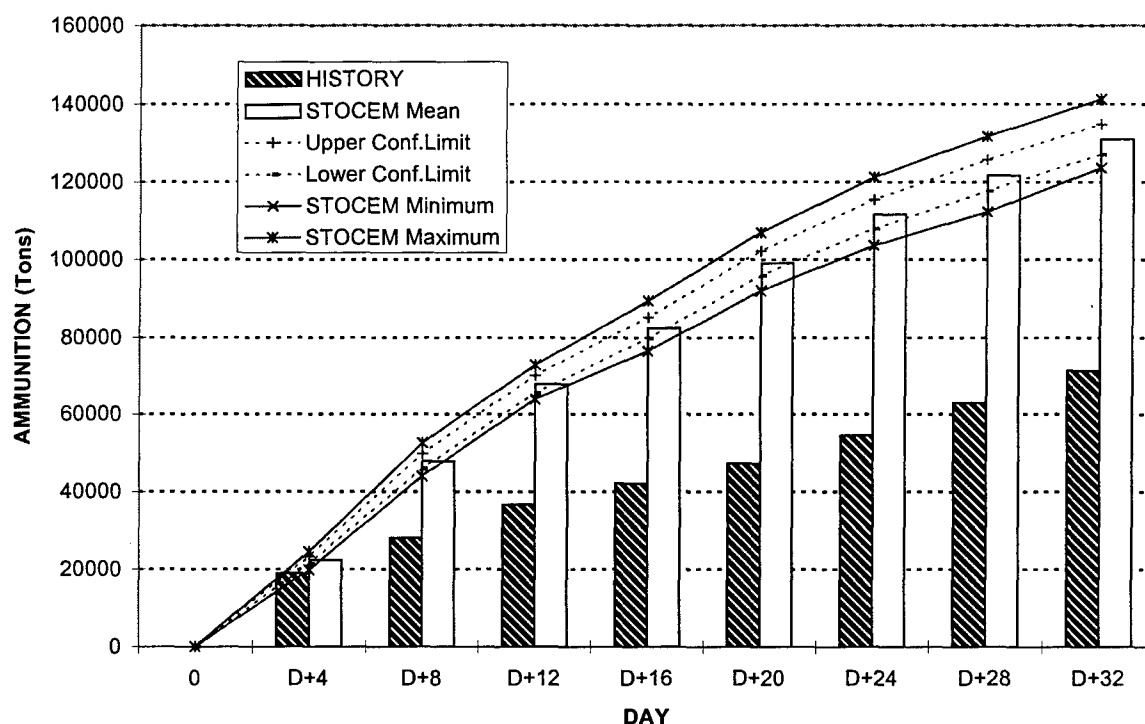
Figure 3-16. Cumulative Consumption of German Ammunition (tons)

3-5. PERSONNEL CASUALTIES

a. Figure 3-17 shows the cumulative permanent losses of US/UK personnel. "Permanent personnel losses" include dead, captured, missing, and hospital patients requiring evacuation from the theater. In reporting cumulative casualties over time, permanent losses are used because a particular soldier can become a permanent loss only once; whereas total casualties may include the same individual more than once if a soldier returns to duty after a wound, illness, or injury. Historical permanent losses exceeded those of the STOCEM base case in the first 4 days of the campaign, presumably due to "the encirclement and surrender of much of the US 106th Infantry Division during that period" (Ref. 1, p 6-7), which was not modeled in the STOCEM base case.

Figure 3-17. Cumulative Permanent Losses of US/UK Personnel

b. Figure 3-18 shows the cumulative permanent losses of German personnel. The STOCEM base case estimates of German permanent losses are smaller than the historical records through D+16, and in close agreement thereafter.

Figure 3-18. Cumulative Permanent Losses of German Personnel

c. Figures 3-19, 3-20, 3-21, and 3-22 show the fractions of daily US/UK personnel casualties that are KIA, WIA, CMIA, and DNBI, respectively. As noted in ARCAS, "STOCEM consistently overestimates KIA and WIA casualties and underestimates CMIA and DNBI casualties" (Ref. 1, p 6-7). Chapter 6 will address this subject more extensively.
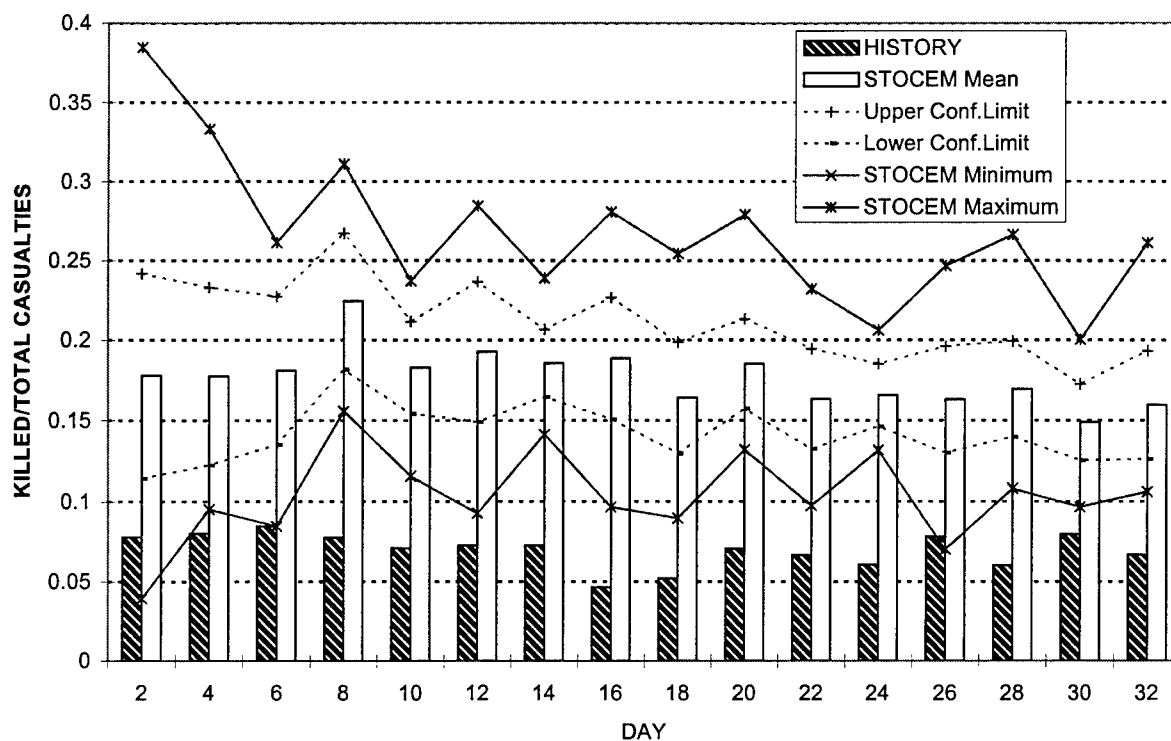
Figure 3-19. Fraction of US/UK Casualties that are Killed
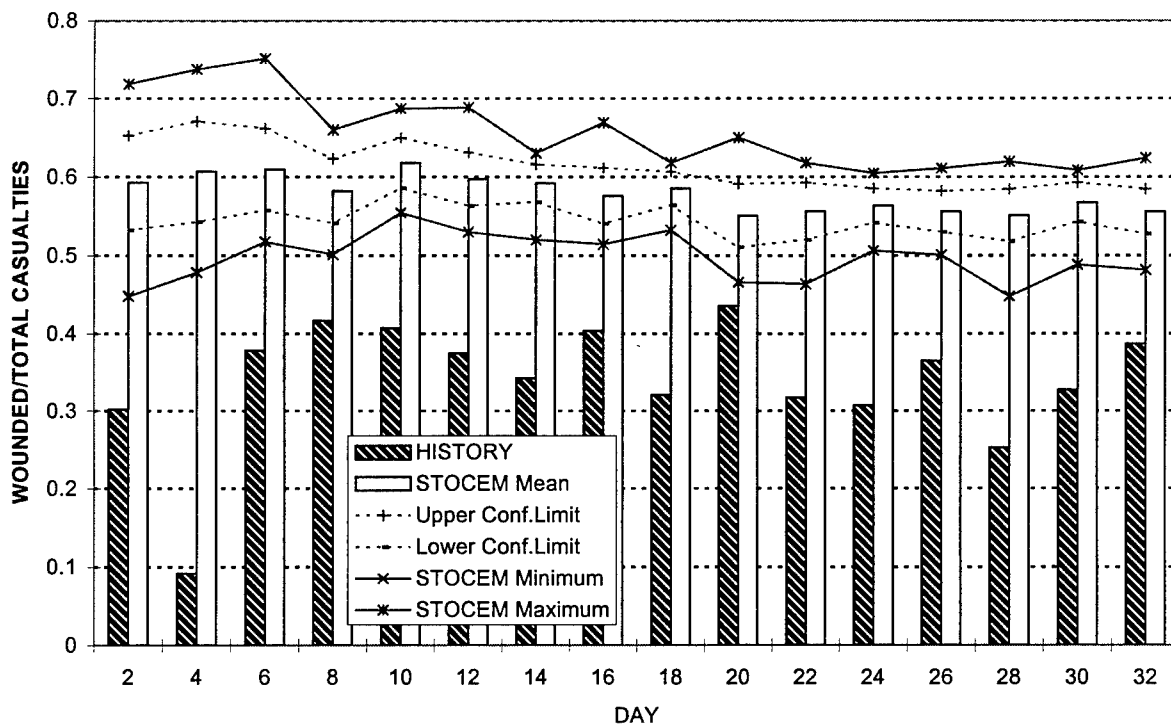
Figure 3-20. Fraction of US/UK Casualties that are Wounded
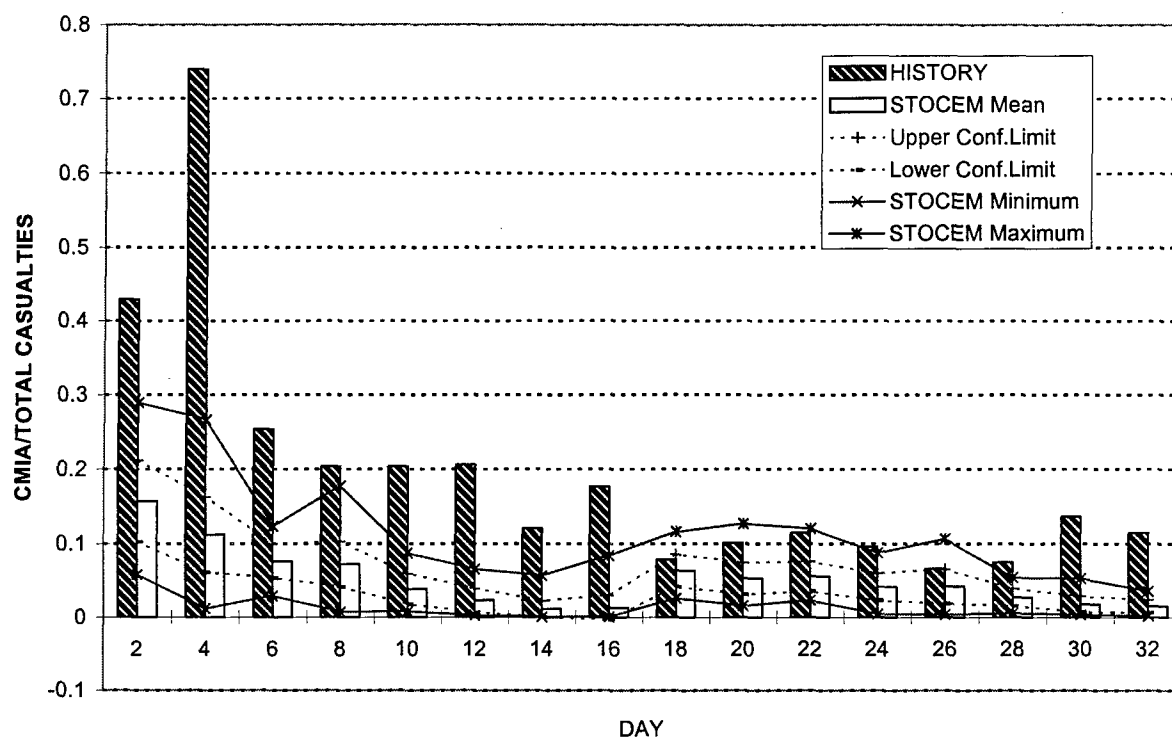
Figure 3-21. Fraction of US/UK Casualties that are Captured/Missing
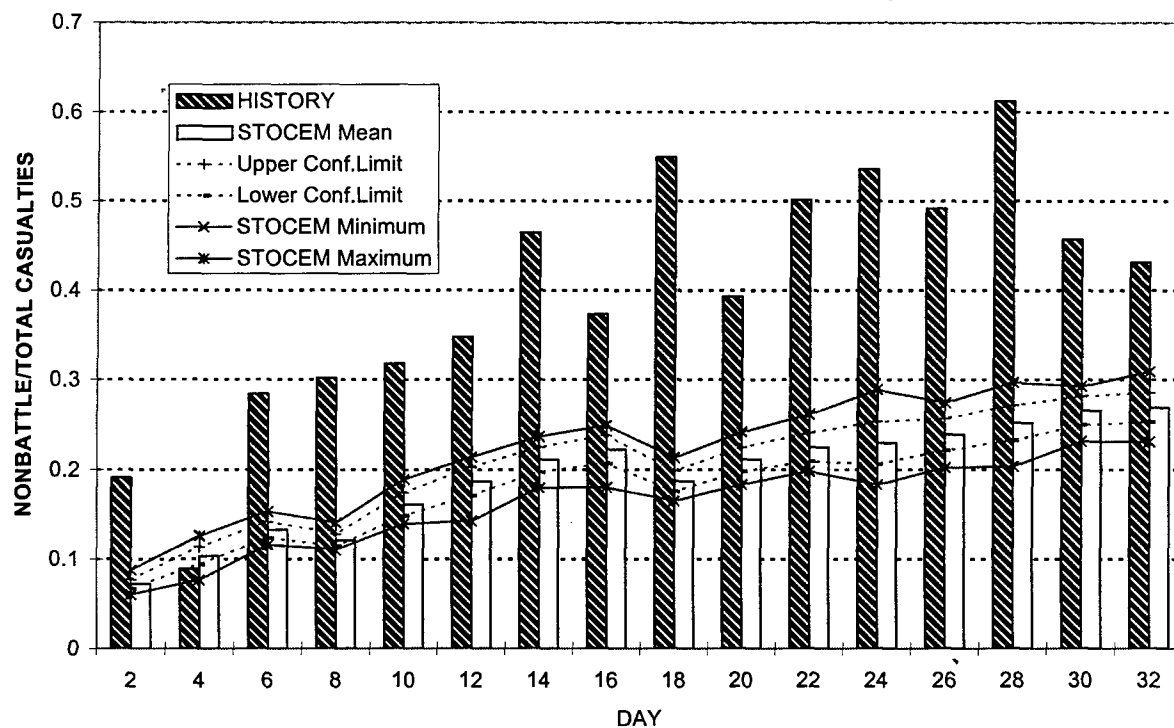
Figure 3-22. Fraction of US/UK Casualties that are DNBI

3-6. OBSERVATIONS

a. Certain elements of the historical data extracted from the ACSDB by ARCAS appear suspect. In particular, the attrition of US/UK antitank/mortar weapons was negligible (0.46 per day) after D+8, even though nearly 6,000 of these weapons remained in combat units at D+32. Also, the amount of German ammunition consumed in the Ardennes Campaign was only 2,232 tons per day, 20 percent of US/UK consumption, although the German force included more than 3,000 artillery tubes/launchers. Attempting to modify STOCEM so that its results are consistent with historical anomalies such as these may lead us to STOCEM changes that are not appropriate for more typical situations.

b. The cumulative permanent losses of US/UK tanks are entirely consistent with the results reported in ARCAS. That is, STOCEM permanent tank losses are close to historical losses from D+5 through D+16, and "historical losses are proportionately higher than STOCEM losses in the first 4 days of the campaign, while they are noticeably less than STOCEM's in the latter half of the campaign" (Ref. 1, p 5-2).

c. The historical record indicates negligible losses of light armor after D+12 and negligible losses of antitank/mortar weapons after D+8, but these weapons continue to suffer significant attrition throughout the campaign in STOCEM. Losses of US/UK antitank/mortars are significantly less in this STOCEM base case than in the STOCEM results reported in ARCAS.

d. US/UK artillery losses are negligible throughout the campaign in STOCEM, but there are significant US/UK artillery losses reported in the historical record.

e. The present STOCEM base case losses of German tanks, light armor, and antitank/mortars after D+16 are significantly greater than the STOCEM losses reported in ARCAS.

f. The consumption of US/UK ammunition in the present STOCEM base case is slightly higher after D+16 than the STOCEM results of ARCAS. Thus, the present STOCEM base case agrees better with historical US/UK ammunition consumption than does the STOCEM simulation of ARCAS.

g. The corrected STOCEM inputs have resulted in a drastic (72 percent) reduction in German ammunition consumption from ARCAS STOCEM results. Nevertheless, the STOCEM consumption of German ammunition remains significantly higher than historical consumption, after D+4.

h. Historical losses of US/UK personnel exceeded those of the STOCEM base case in the first 4 days of the campaign, presumably due to "the encirclement and surrender of much of the US 106th Infantry Division during that period" (Ref. 1, p 6-7), which was not modeled in the STOCEM base case.
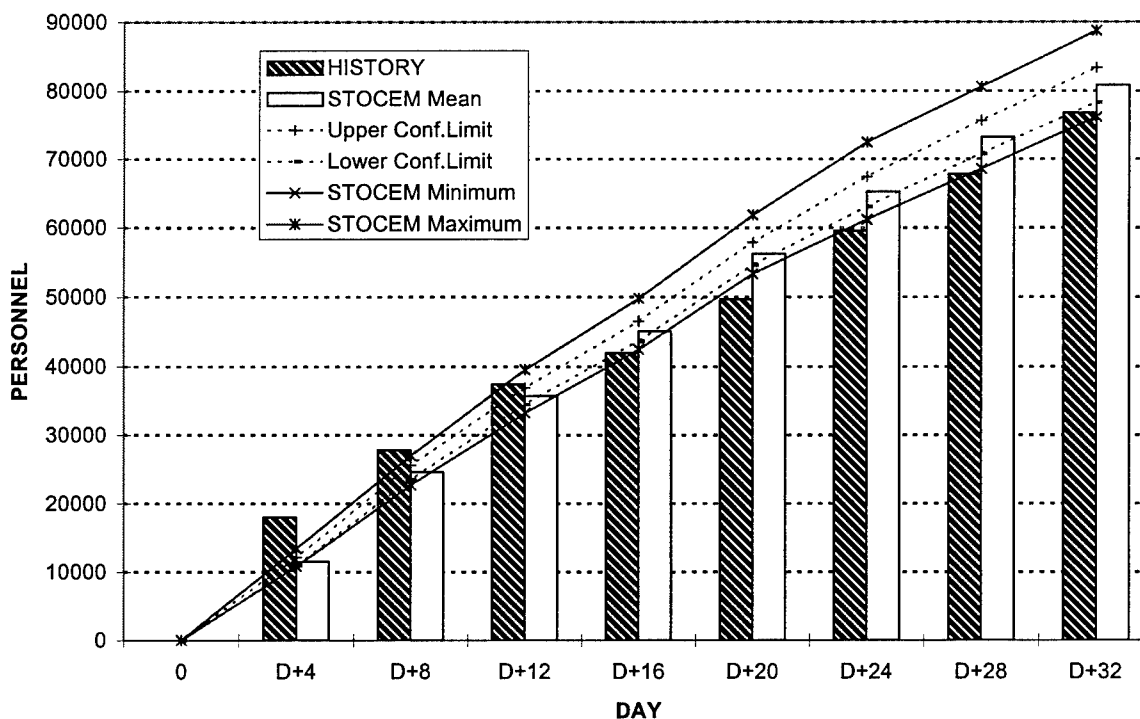
i. The STOCEM base case estimates of German personnel losses are smaller than the historical records through D+16, and in close agreement thereafter.
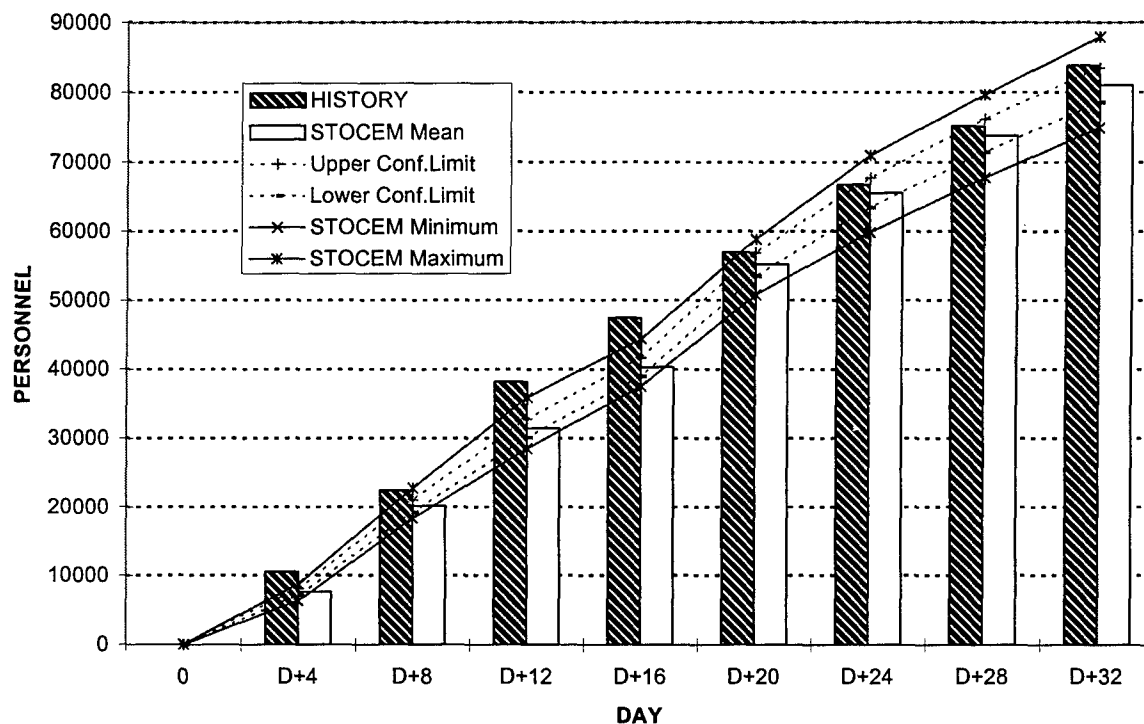
j. As noted in ARCAS, "STOCEM consistently overestimates KIA and WIA casualties and underestimates CMIA and DNBI casualties" (Ref. 1, p 6-7).

CHAPTER 4

# LIMIT ON DURATION OF ATTACKS

4-1. MODIFICATION OF STOCEM

    a. ARCAS found that the Ardennes Campaign historical results support the hypothesis "that a sustained rapid force advance is often punctuated by intervals of reduced mobility and aggressiveness due to tactical and logistical constraints, caution in the face of uncertainty, and the need to regroup to conserve the integrity of its organization. STOCEM does not appear to simulate this tendency to a sufficient degree." (Ref. 1, p 3-17)

    b. In response to these findings, STOCEM was modified to permit the STOCEM user to specify by input the maximum duration, in 12-hour cycles, of a sustained attack by any maneuver unit. The user now can specify the maximum number of consecutive 12-hour combat cycles a Blue brigade may continue attacking and, separately, the maximum number of consecutive 12-hour cycles a Red division may attack. When a Blue brigade or Red division has attacked for the number of consecutive cycles specified by input, that brigade must assume a nonattack mission for at least 12 hours before attacking again.

4-2. 24-HOUR LIMIT ON BLUE AND RED ATTACK. The first simulations we report using this STOCEM modification were executed with an input limit of 24 hours on duration of attack for both the Blue brigades and Red divisions in STOCEM. Sixteen replications of STOCEM were executed for this case, as in the STOCEM base case and in ARCAS.

a. US/UK Equipment Losses

    (1) Figures 4-1 to 4-3 provide a comparison of the equipment losses of US/UK tanks, light armor, and antitank/mortars among the historical results (vertical shaded bars), base case results (solid lines enclosing confidence intervals), and the results of this STOCEM variation (dashed lines enclosing confidence intervals). Confidence intervals are defined as in paragraph 2-2h, providing at leas 90 percent confidence. In these figures the STOCEM mean values are not displayed, to reduce clutter. The STOCEM mean is always the center (mid point) of each confidence interval.
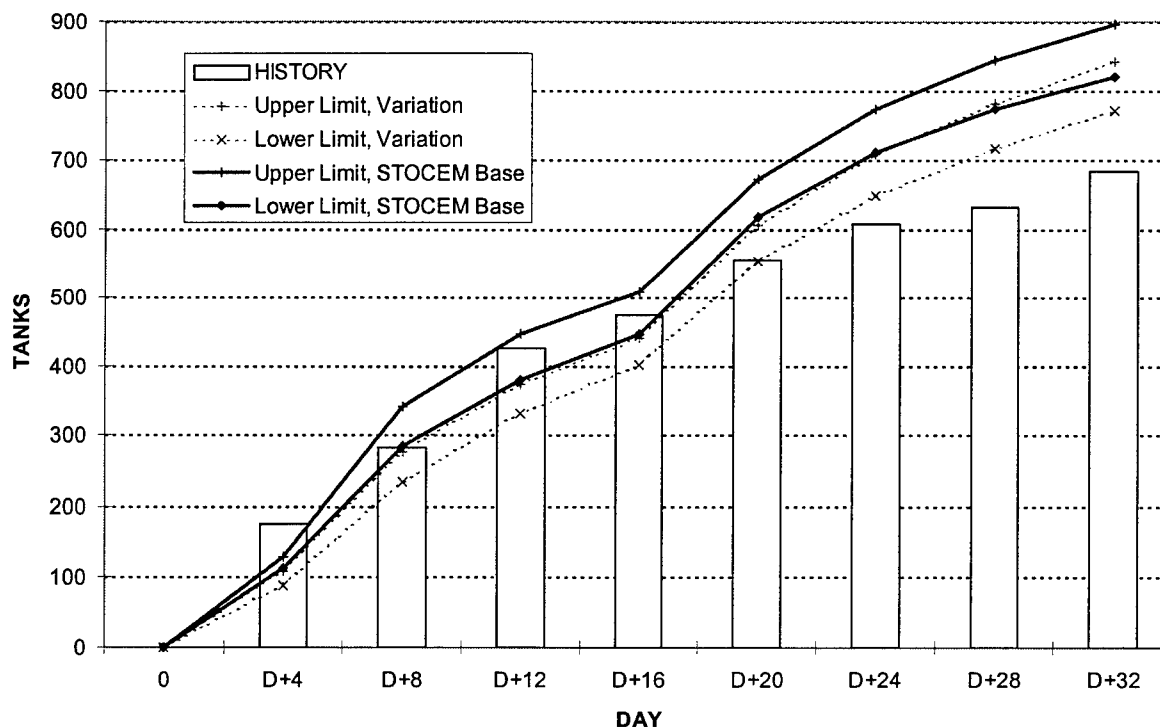
Figure 4-1. Cumulative Permanent Losses of US/UK Tanks, 24-Hour Limit on Attacks, Both Sides
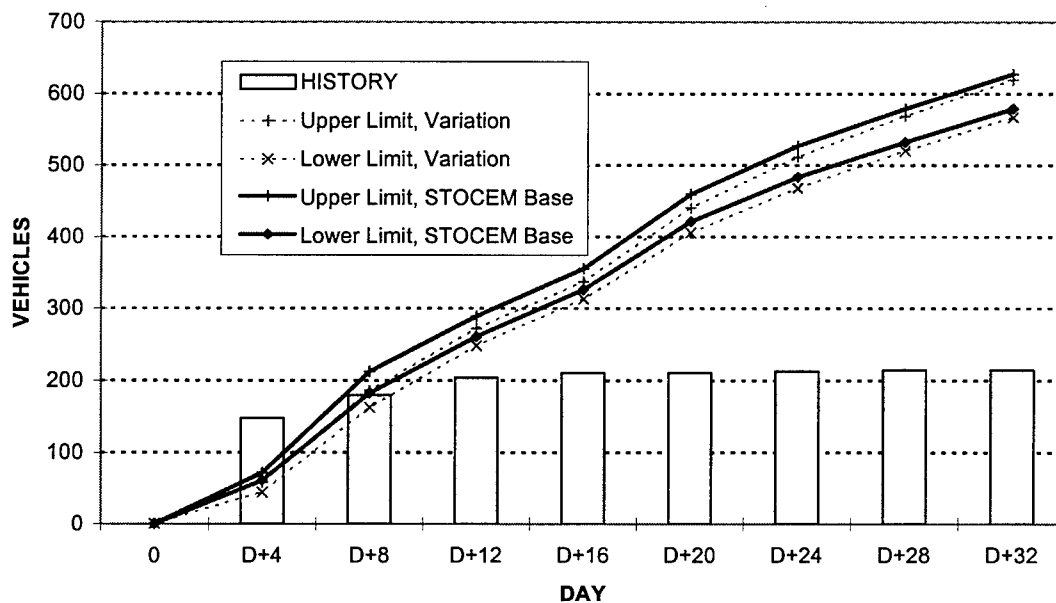
Figure 4-2. Cumulative Permanent Losses of US/UK Light Armor, 24-Hour Limit on Attacks, Both Sides

Figure 4-3. Cumulative Permanent Losses of US/UK Antitank/Mortars, 24-Hour Limit on Attacks, Both Sides

(2) Figures 4-1, 4-2, and 4-3 show that US/UK equipment losses in this variation decrease from the STOCEM base case, as we expect from the decrease in the opportunities of both sides' units to attack in this STOCEM variation. In these figures, the decrease generally brings the equipment losses closer to the historical losses. However, Figure 4-1 shows that the US/UK tank losses in the first 16 days of the campaign are significantly closer to history in the STOCEM base case than in this variation. In the first 16 days, it is German divisions, rather than US/UK units, that are attacking, whereas in the last half of the campaign, it is generally the US/UK forces that are on the attack.

(3) Figure 4-4 compares the percentages of US/UK units that are attacked, between the STOCEM base case (solid lines) and this variation (dashed lines). It is clear from Figure 4-4 that this variation reduces German attacks, particularly in the first 12 days of the campaign, from the STOCEM base case.
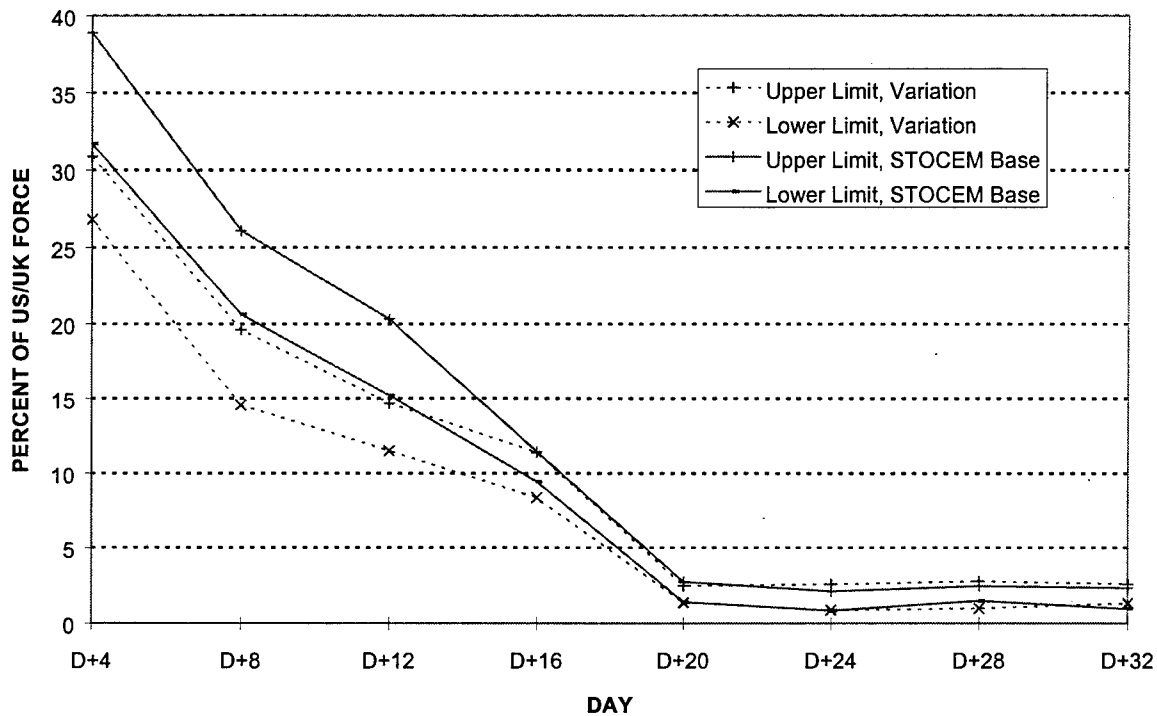
Figure 4-4. Frequency of German Attack, 24-Hour Limit on Attacks, Both Sides

b. German Equipment Losses. Figures 4-5 to 4-7 provide a comparison of the equipment losses of German tanks, light armor, and antitank/mortars among the historical results (bars), base case results (solid lines enclosing confidence intervals, defined as above), and the results of this STOCEM variation (dashed lines enclosing confidence intervals). These figures show that this variation also produces lower German losses of equipment than the STOCEM base case, an expected consequence of the reduced frequency of attack by both sides in this variation.

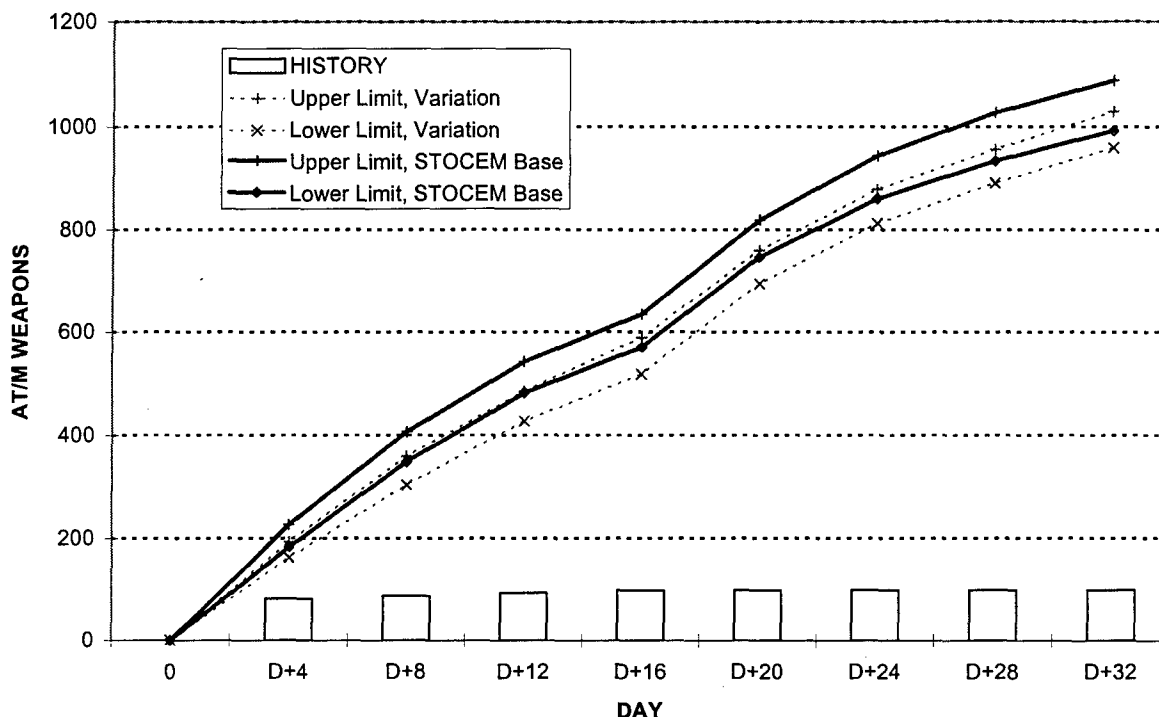**Figure 4-5. Cumulative Permanent Losses of German Tanks, 24-Hour Limit on Attacks, Both Sides**
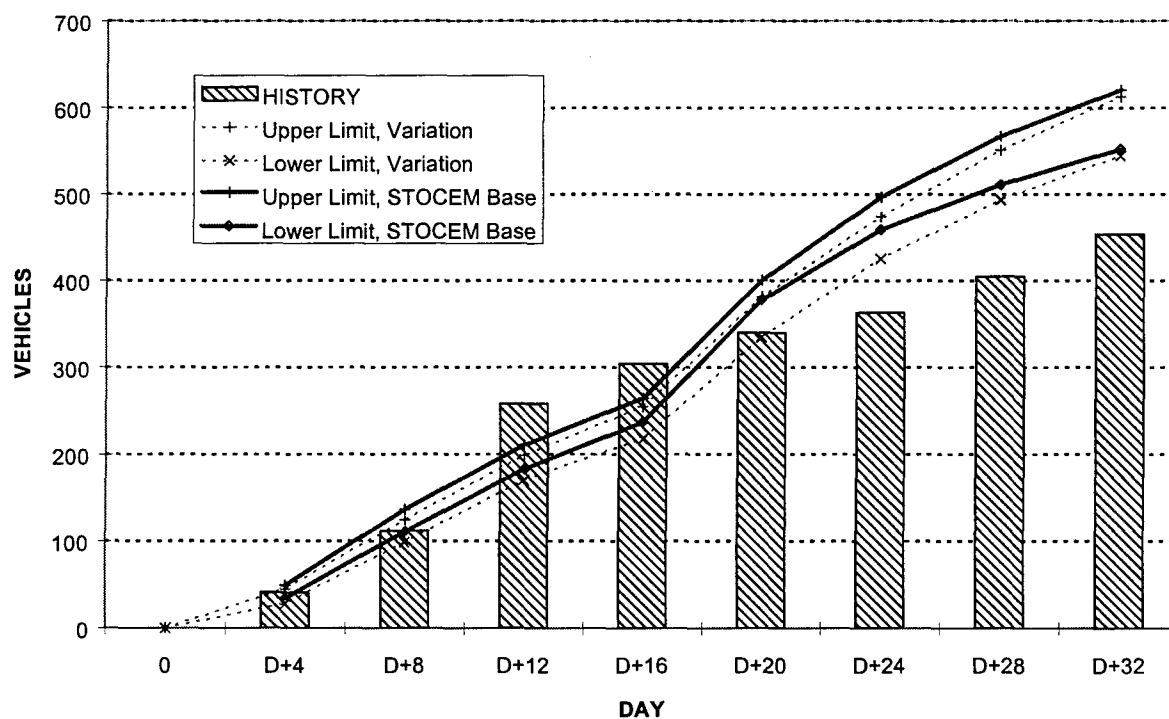
Figure 4-6. Cumulative Permanent Losses of German Light Armor, 24-Hour Limit on Attacks, Both Sides

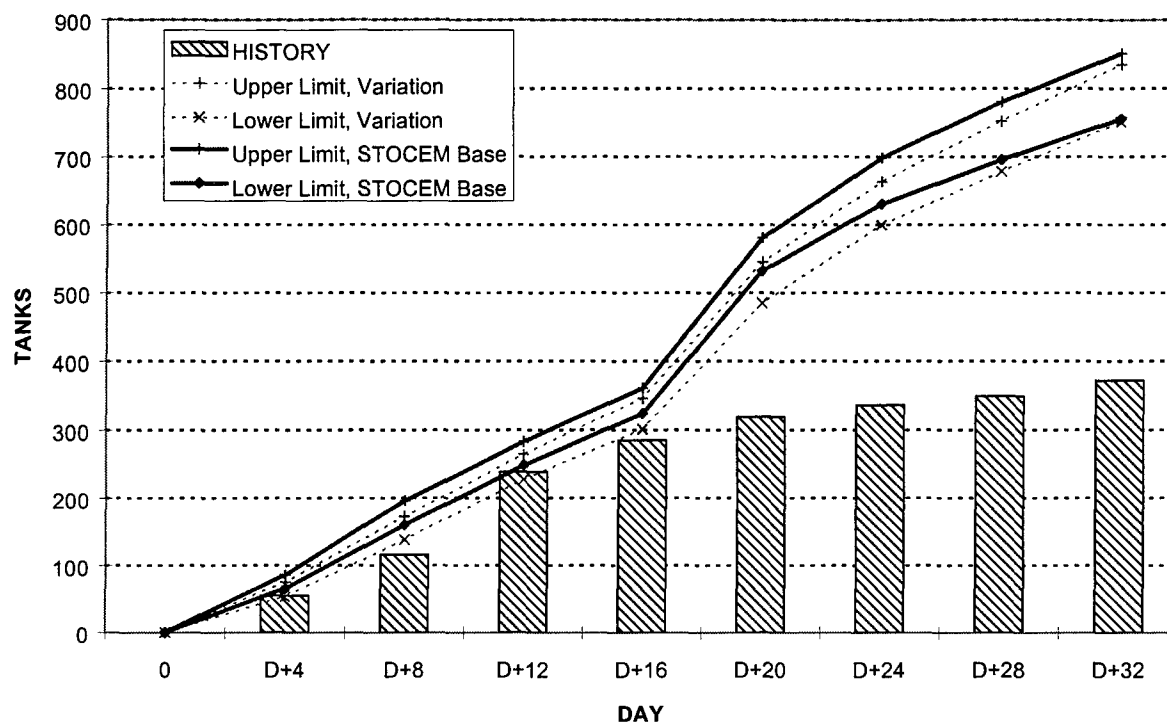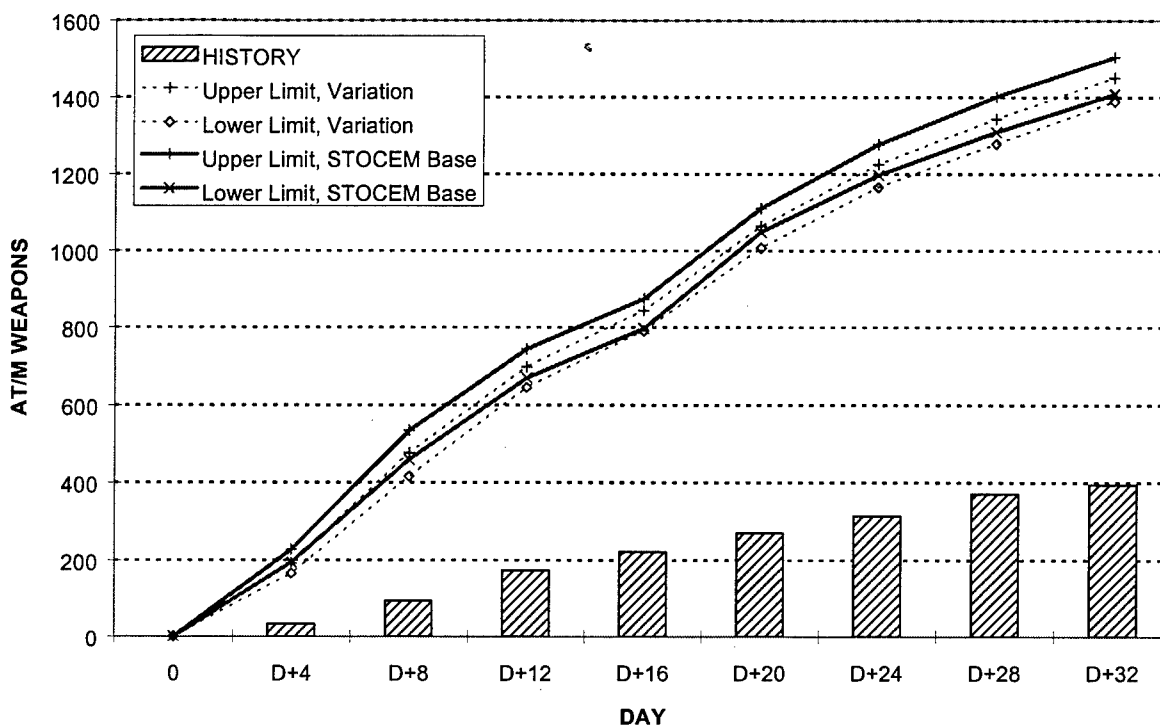**Figure 4-7. Cumulative Permanent Losses of German Antitank/Mortars, 24-Hour Limit on Attacks, Both Sides**

   c. **FEBA Movement.** Figure 4-8 displays over a map at D+8 the location of the historical FEBA, as calculated by ARCAS (solid dark line), the average of the 16 replications of the STOCEM base case, as reported in Chapter 3 (dashed dark line), and this STOCEM variation (white line). We observe that the maximum D+8 penetration, "bulge," by German forces in this variation falls far short of either the STOCEM base case or the historical outcome. This again is a consequence of the reduction in attacks by the German divisions permitted in this STOCEM variation.

Figure 4-8. D+8 FEBA Locations: History, Base Case, and 24-Hour Limit on Attacks, Both Sides

4-3. 12-HOUR LIMIT ON BLUE ATTACK. In the historical Ardennes Campaign, it was the US/UK forces, more than the German divisions, whose attacks were "often punctuated by intervals of reduced mobility and aggressiveness due to tactical and logistical constraints, caution in the face of uncertainty, and the need to regroup" (Ref. 1, p 3-17). For this reason, we executed 16 replications of a second STOCEM variation that limits the US/UK brigades to a maximum of one consecutive 12-hour combat cycle attacking, the shortest possible duration of attack in STOCEM, while German divisions are permitted to attack for up to 16 consecutive 12-hour cycles in this variation.

a. FEBA Movement. Figures 4-9 and 4-10 display over a map at D+8 and D+20, respectively, the location of the historical FEBA, as calculated by ARCAS (solid dark line), the average of the 16 replications of the STOCEM base case (dashed dark line), and the average of the 16 replications of this second STOCEM variation (white line). We observe that the D+8 (Figure 4-9) average FEBA locations for this variation and the STOCEM base case are the same, because this variation permits German units to attack through D+8 without pause as in the STOCEM base case. By D+20 (Figure 4-10), there is a difference between the average FEBA locations for this variation and the STOCEM base case, because US/UK brigades are permitted to attack for only two consecutive 12-hour cycles in this variation, and consequently US/UK forces do not retake as much terrain in this variation as in the STOCEM base case. The average D+20 FEBA location for this variation is closer to the historical D+20 FEBA in the central "bulge" sector of the campaign than the average D+20 FEBA of the STOCEM base case is.


Figure 4-9. D+8 FEBA Locations: History, Base Case, and 12-Hour Limit on US/UK Attacks

Figure 4-10. D+20 FEBA Locations: History, Base Case, and 12-Hour Limit on US/UK Attacks

b. US/UK Equipment Losses. Figures 4-11 to 4-13 provide a comparison of the equipment losses of US/UK tanks, light armor, and antitank/mortars among the historical results (bars), base case results (solid lines enclosing confidence intervals), and the results of this STOCEM variation (dashed lines enclosing confidence intervals). Artillery losses are not shown, because US/UK artillery losses in this variation are negligible, as in the STOCEM base case. For each type of US/UK equipment, the permanent losses are reduced from the STOCEM base case, because of the decrease in attacks by US/UK brigades permitted in this variation. These reductions bring the losses of equipment marginally closer to the historical results. However, in no case does the confidence interval of STOCEM results of this variation include the historical equipment losses, except where the STOCEM base case confidence interval already includes the historical result.
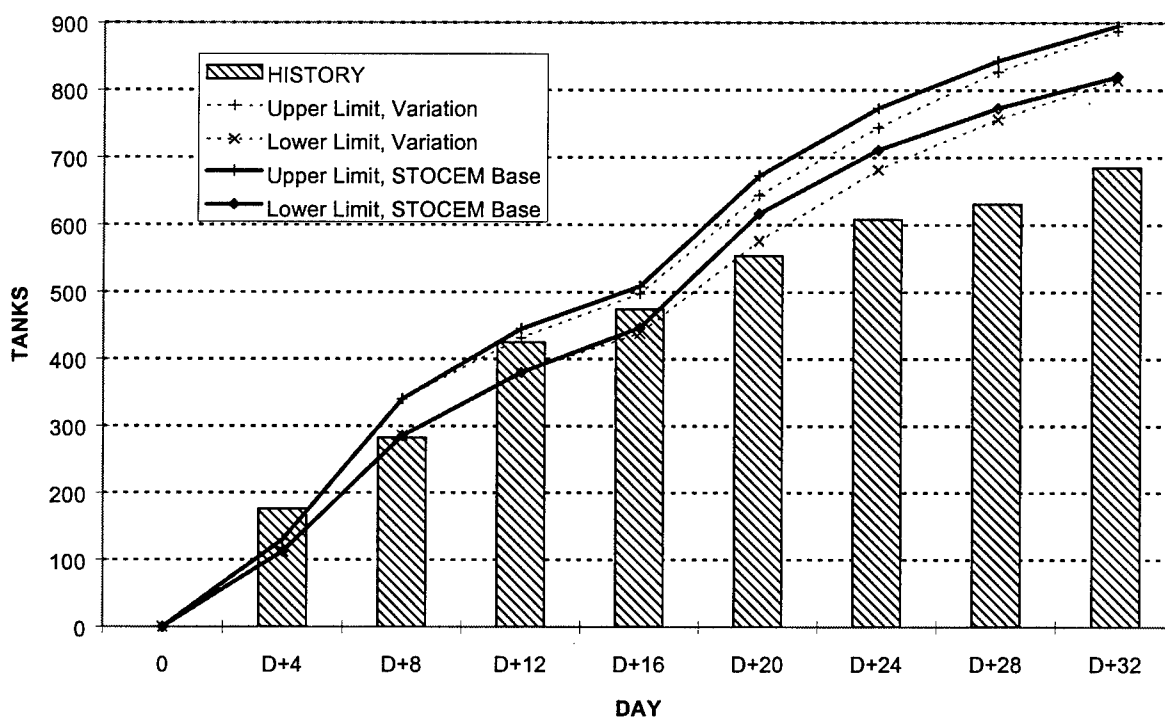
Figure 4-11. Cumulative Permanent Losses of US/UK Tanks, 12-Hour Limit on US/UK Attacks
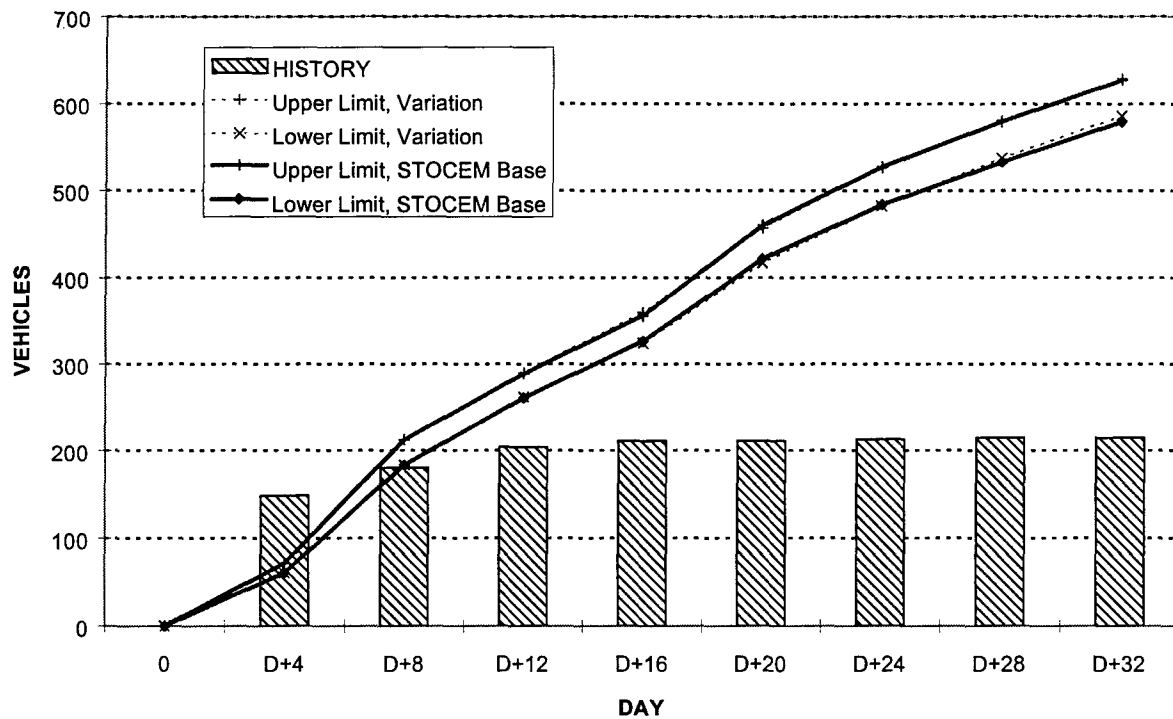
Figure 4-12. Cumulative Permanent Losses of US/UK Light Armor,12-Hour Limit on US/UK Attacks

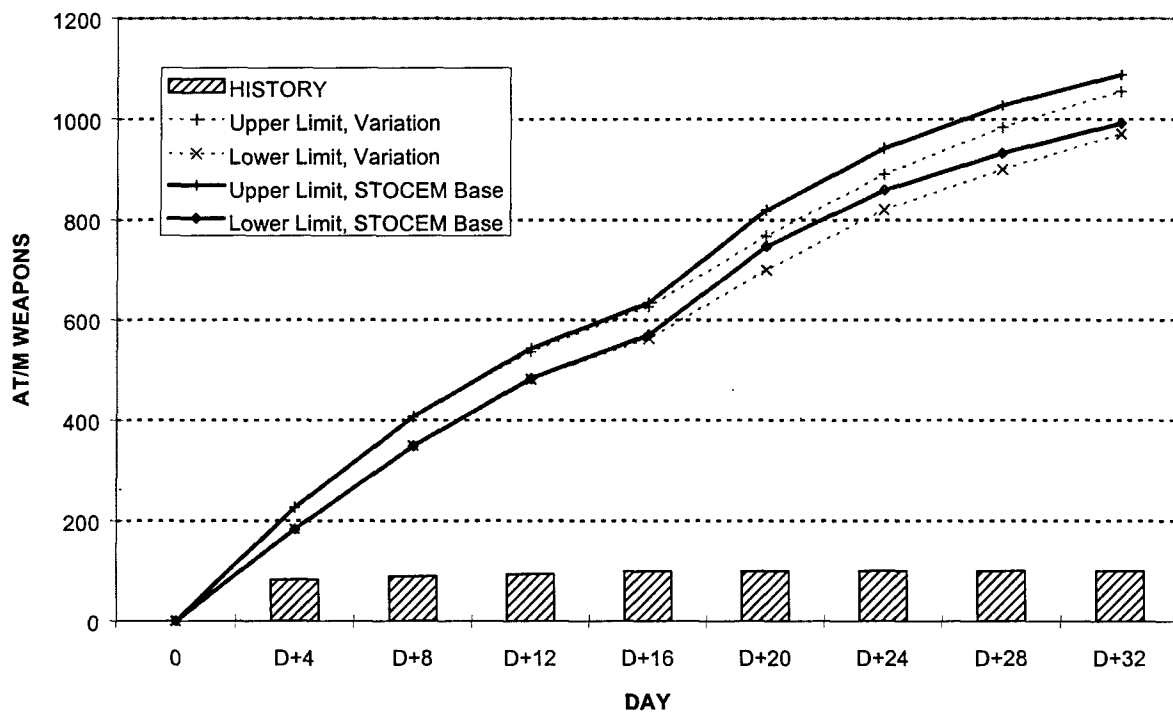**Figure 4-13. Cumulative Permanent Losses of US/UK Antitank/Mortars, 12-Hour Limit on US/UK Attacks**

c. **German Equipment Losses.** Figures 4-14 to 4-17 provide a comparison of the equipment losses of German tanks, light armor, antitank/mortars, and artillery, respectively, among the historical results (bars), base case results (solid lines enclosing confidence intervals), and the results of this STOCEM variation (dashed lines enclosing confidence intervals). For each type of German equipment, the permanent losses are reduced from the STOCEM base case, at least through D+24, because of the decrease in attacks by US/UK brigades permitted in this variation. Losses of German tanks and light armor are higher after D+24 in this variation than in the STOCEM base case, because the reduction in attacks prior to D+24 by US/UK brigades causes US/UK forces to reach their objectives later in this variation, so more US/UK forces continue attacking after D+24 in this variation to reach their objectives. Figure 4-18 compares the percentages of US/UK units that are attacking, between the STOCEM base case (solid lines) and this variation (dashed lines).

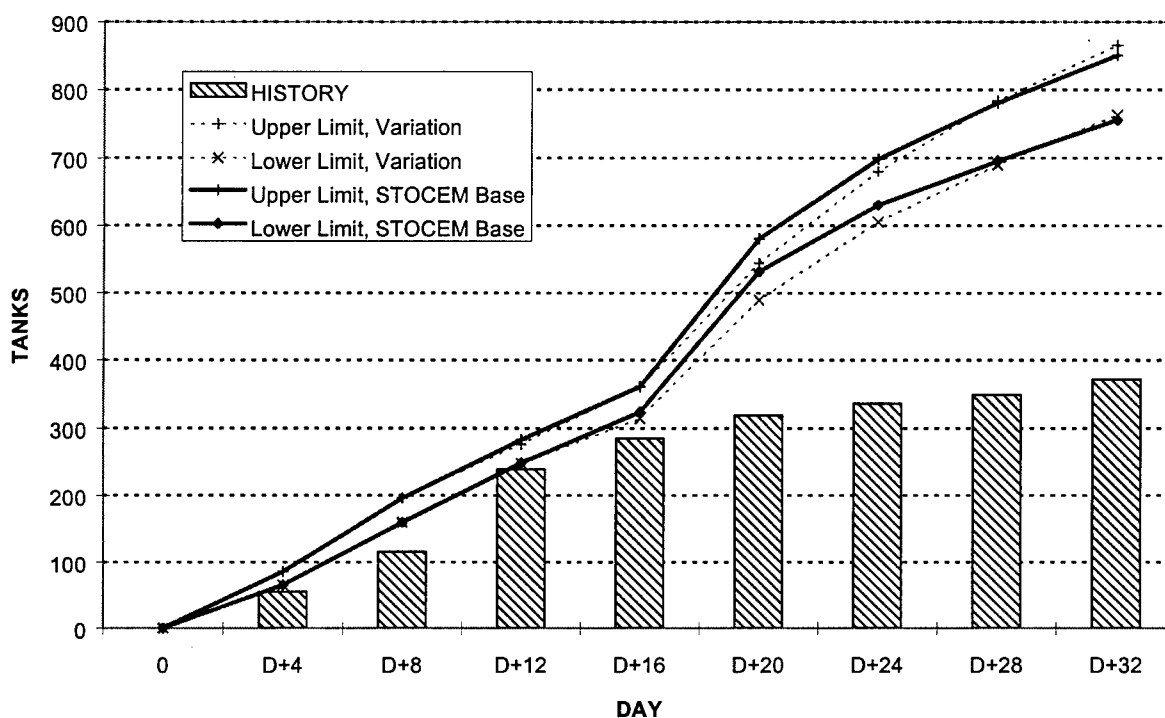**Figure 4-14. Cumulative Permanent Losses of German Tanks, 12-Hour Limit on US/UK Attacks**

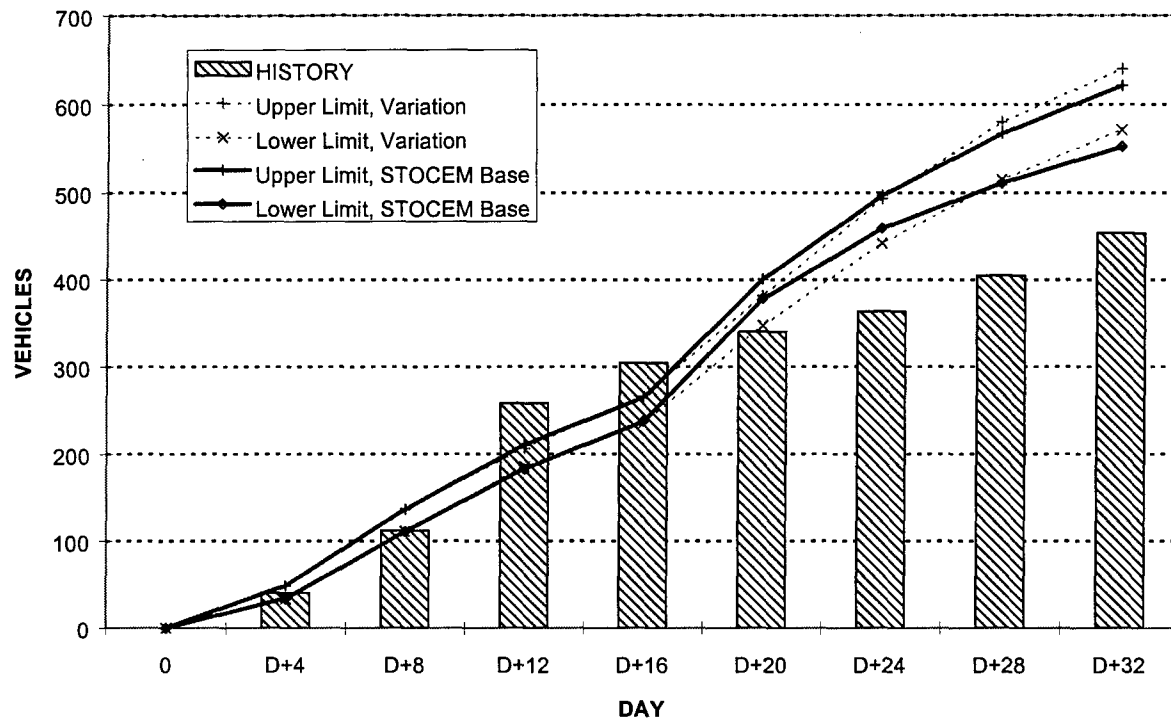**Figure 4-15. Cumulative Permanent Losses of German Light Armor, 12-Hour Limit on US/UK Attacks**

Figure 4-16. Cumulative Permanent Losses of German Antitank/Mortars, 12-Hour Limit on US/UK Attacks
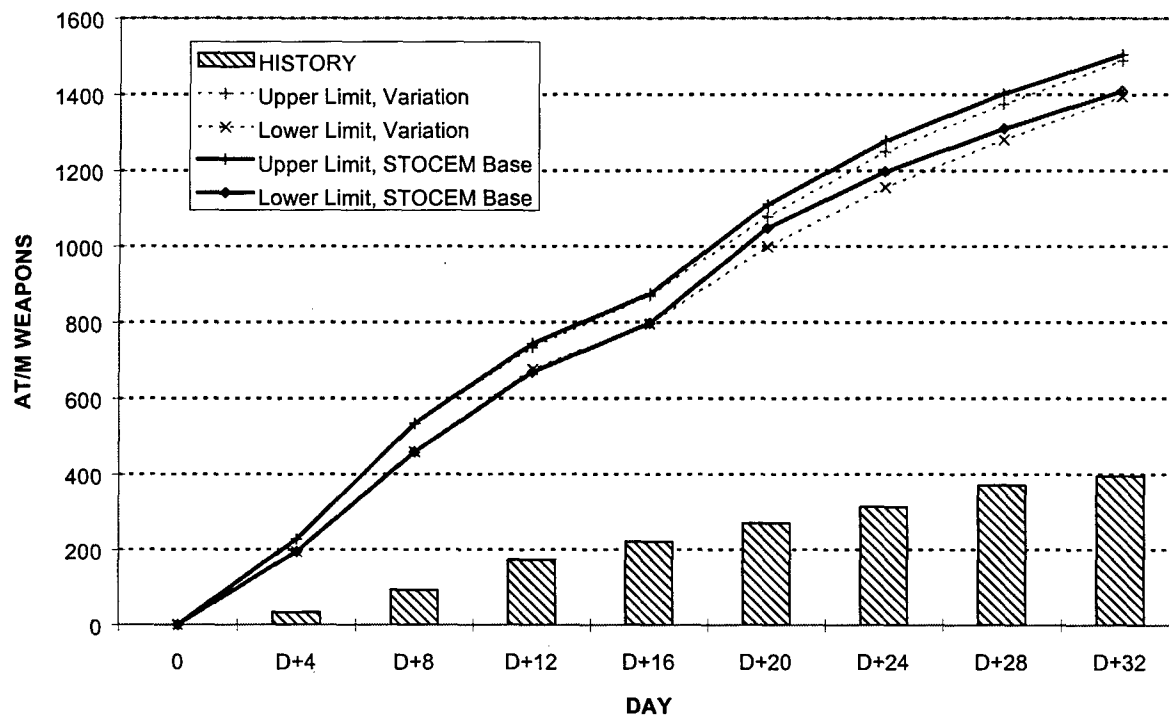
Figure 4-17. Cumulative Permanent Losses of German Artillery, 12-Hour Limit on US/UK Attacks
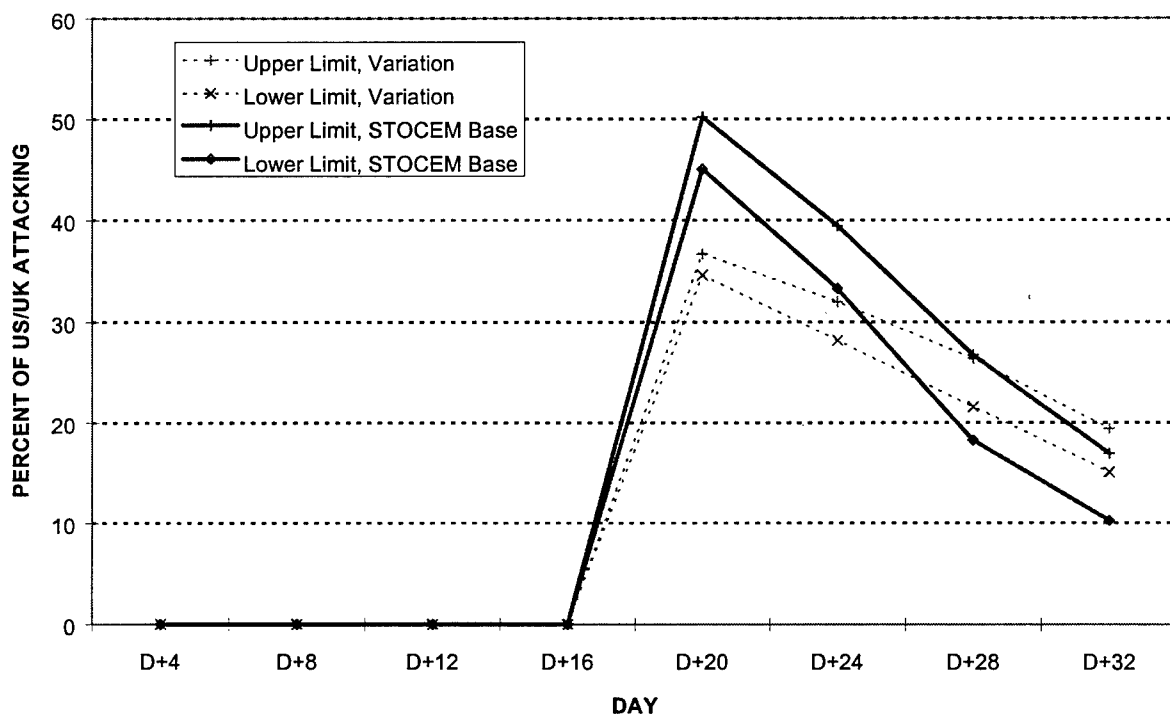
Figure 4-18. Frequency of US/UK Attack, 12-Hour Limit on US/UK Attacks

d. Ammunition Consumption. Figures 4-19 and 4-20 provide a comparison of the US/UK and German ammunition consumption, respectively, among the historical results (bars), base case results (solid lines enclosing confidence intervals), and the results of this STOCEM variation (dashed lines enclosing confidence intervals). Both sides' consumption of ammunition decreases slightly from the base case to this STOCEM variation because of the reduced quantity of US/UK attacks in the second half of the campaign in this variation. German consumption of ammunition remains significantly higher in this variation than in historical results.
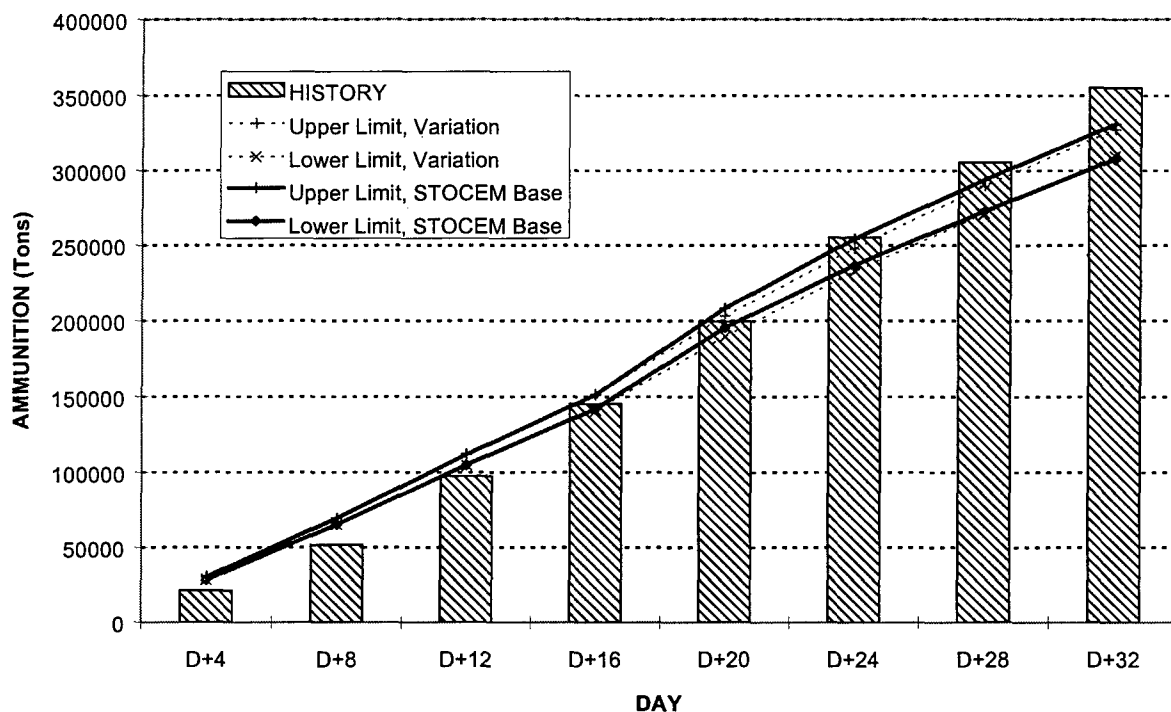
Figure 4-19. Cumulative Consumption of US/UK Ammunition, 12-Hour Limit on US/UK Attacks
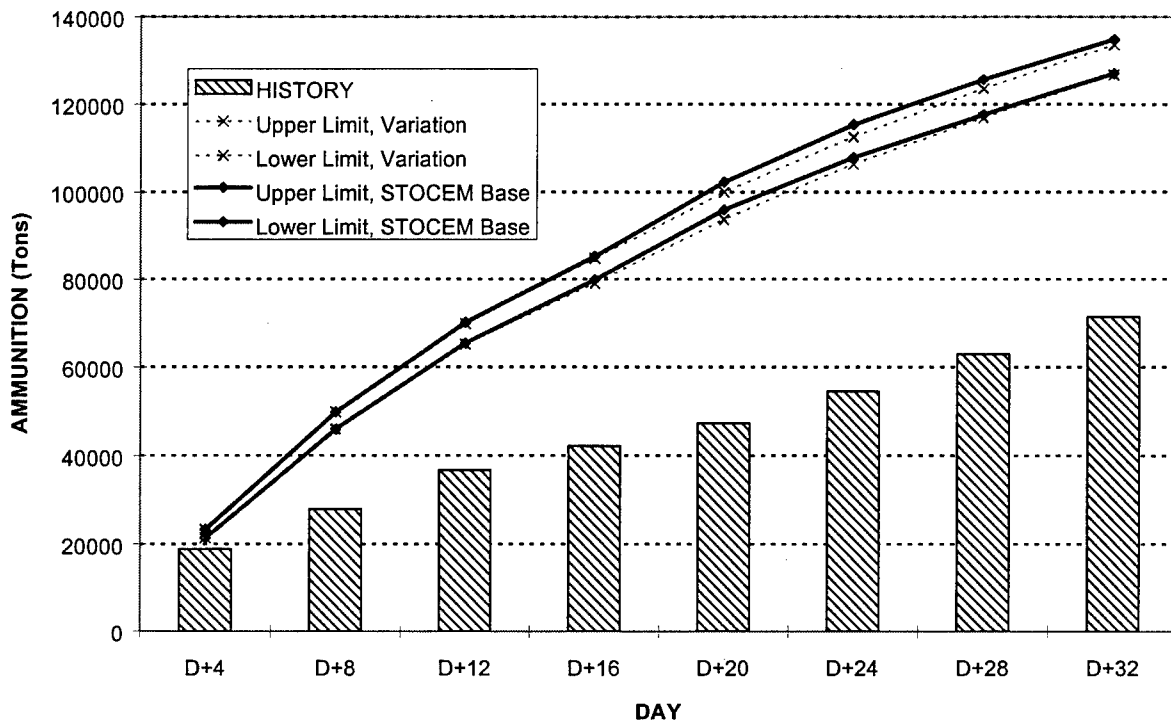
Figure 4-20. Cumulative Consumption of German Ammunition, 12-Hour Limit on US/UK Attacks

e. Personnel Losses. Figures 4-21 and 4-22 provide a comparison of the US/UK and German permanent personnel losses, respectively, among the historical results (bars), base case results (solid lines enclosing confidence intervals), and the results of this STOCEM variation (dashed lines enclosing confidence intervals). US/UK permanent personnel losses--dead, captured, missing, and patients requiring evacuation from theater--in this variation changed very little from the STOCEM base case. German permanent personnel losses in this variation decreased from the STOCEM base case, making the casualties of this variation further from the historical results than were those of the STOCEM base case.
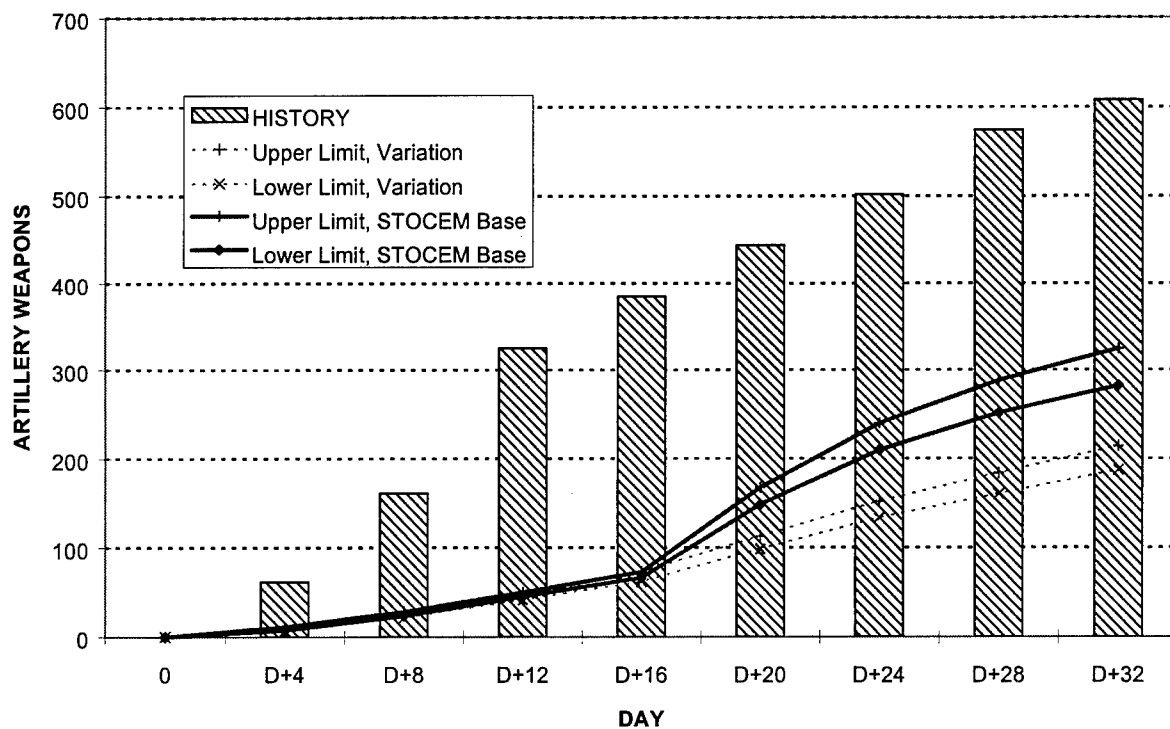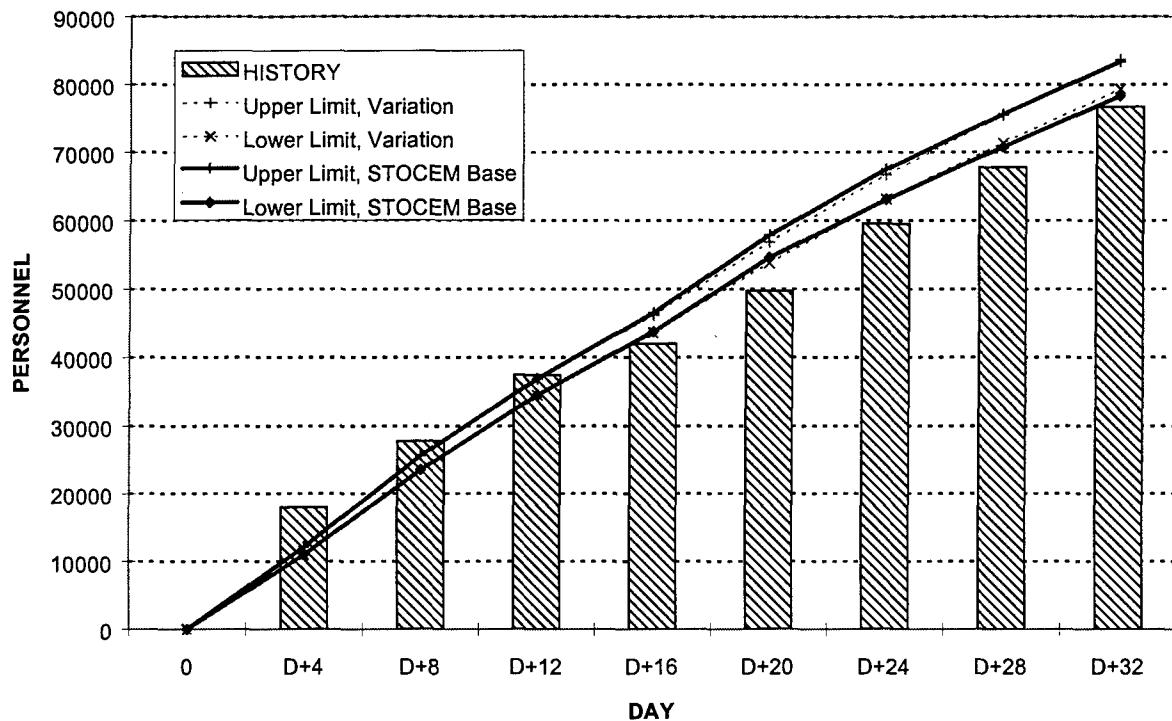
Figure 4-21. Cumulative Permanent Losses of US/UK Personnel, 12-Hour Limit on US/UK Attacks
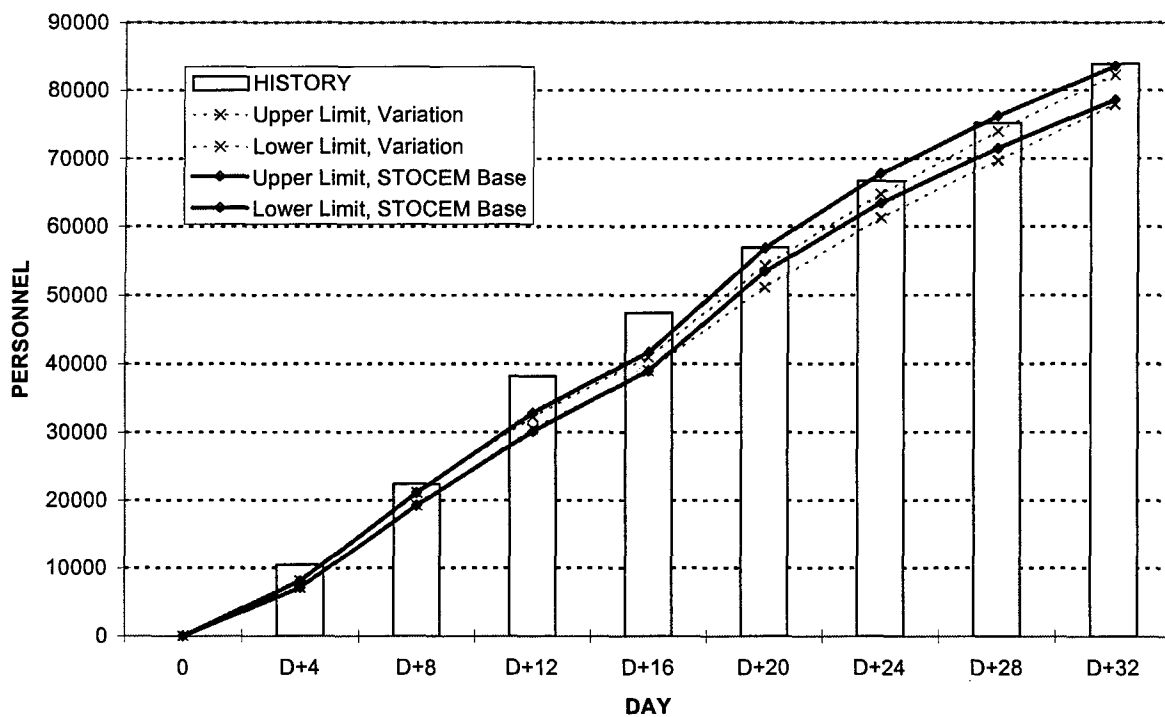
**Figure 4-22. Cumulative Permanent Losses of German Personnel, 12-Hour Limit on US/UK Attacks**

4-4. OBSERVATIONS

a. The ability of a STOCEM user to limit the duration of attacks by the units of each side is a useful improvement to our campaign simulation capability, because it allows model users to represent possibly different leadership, organizational, and logistical capabilities and limitations of the different forces to be modeled. Providing this greater flexibility to model users is always worthwhile, even if the model users elect not to limit the duration of attacks of either side in a particular scenario. Along with the ability to limit the duration of attacks for either side comes the challenge to STOCEM users to estimate what these limits should be. For how many consecutive half-days can an attacking Iraqi division sustain an attack?

b. Limiting the duration of attacks by German divisions to 24 hours in simulating the Ardennes Campaign produces STOCEM results--particularly the distance advanced by the Germans in the sectors of greatest penetration--that are less consistent with history than the STOCEM base case was.

c. Limiting the duration of attacks by US/UK brigades to 12 hours, while allowing German divisions to attack for 8 consecutive days, yields STOCEM results that generally agree with history better than the STOCEM base case does. However, the historical results do not fall within the STOCEM confidence intervals for appreciably more outcome measures of this variation than of the STOCEM base case. Losses of German artillery, which are lower in the STOCEM base case than in historical results, are reduced even further from history by the limit on duration of Blue attacks.

CHAPTER 5

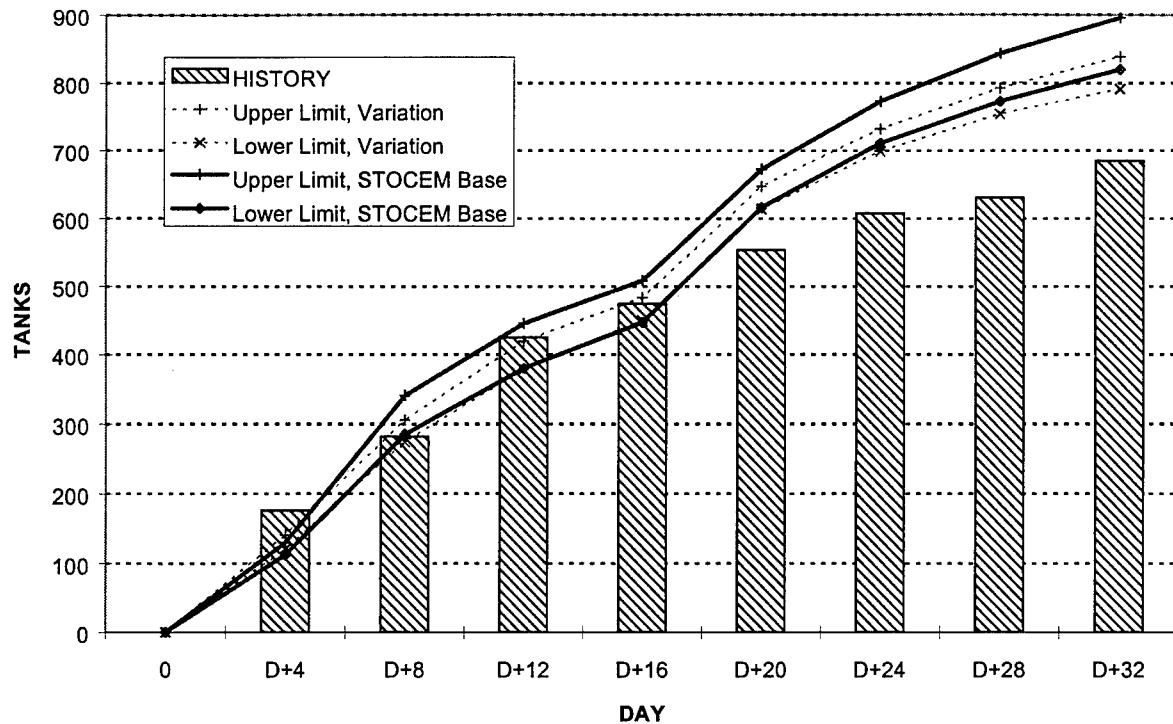## BREAKTHROUGH AND OVERRUN

5-1. MODIFICATION OF STOCEM

a. ARCAS recommended "modifying STOCEM to simulate a 'breakthrough' attack posture, for a limited duration, generating accelerated defender systems attrition and CMIA/DNBI, related to speed and overwhelming force advantage" (Ref. 1, p vi).

b. In response to this recommendation, STOCEM was modified to permit the representation of breakthrough/overrun whenever the attacking force in a STOCEM subsector achieves an overwhelming advantage in combat worth ratio. User inputs to STOCEM establish the attacker/defender force ratio threshold above which breakthrough occurs and specify the fraction of the defending unit's personnel in the subsector that become captured/missing when the unit is overrun. A consequence of a breakthrough/overrun is that all repairable damaged vehicles in the unit that is overrun in the subsector are abandoned and therefore permanently lost. Another effect of breakthrough/overrun is that the distance advanced by the attacker in a breakthrough sector is calculated as if the attacker were unopposed, at the maximum rate for the terrain type; but STOCEM limits on the length of exposed flanks continue to constrain the attacker's advance in a breakthrough. Consumption of ammunition and losses of antitank/mortar weapons, which are not repairable in STOCEM, are not affected by breakthrough/overrun, as presently modeled.

5-2. STOCEM SIMULATIONS. The simulations we report using this STOCEM modification were executed with an input threshold of 6.0 for breakthrough. That is, breakthrough/overruns occur whenever the attacker/defender combat worth ratio exceeds 6.0 in a STOCEM subsector. STOCEM inputs for these simulations specify that 10 percent of the overrun unit's personnel in the subsector become CMIA casualties, consistent with the limited records of the US/UK units that surrendered in the Ardennes Campaign. No limits were placed on the duration of attacks by either side in this STOCEM variation. Sixteen replications of STOCEM were executed for this case, as in the STOCEM base case and in ARCAS.

a. US/UK Equipment Losses

(1) Figures 5-1 to 5-3 provide a comparison of the equipment losses of US/UK tanks, light armor, and antitank/mortars among the historical results (bars), base case results (solid lines enclosing confidence intervals), and the results of this STOCEM variation (dashed lines enclosing confidence intervals). Confidence intervals are defined as in previous chapters, yielding greater than 99 percent confidence under the approximate normality assumptions of the Student-Fisher t-statistic, and at least 90 percent confidence without the normality assumptions. Figures 5-1, 5-2, and 5-3 show that US/UK tank, light armor, and antitank/mortar losses in this variation do not change appreciably from the STOCEM base case.

Figure 5-1. Cumulative Permanent Losses of US/UK Tanks, Breakthrough/Overrun
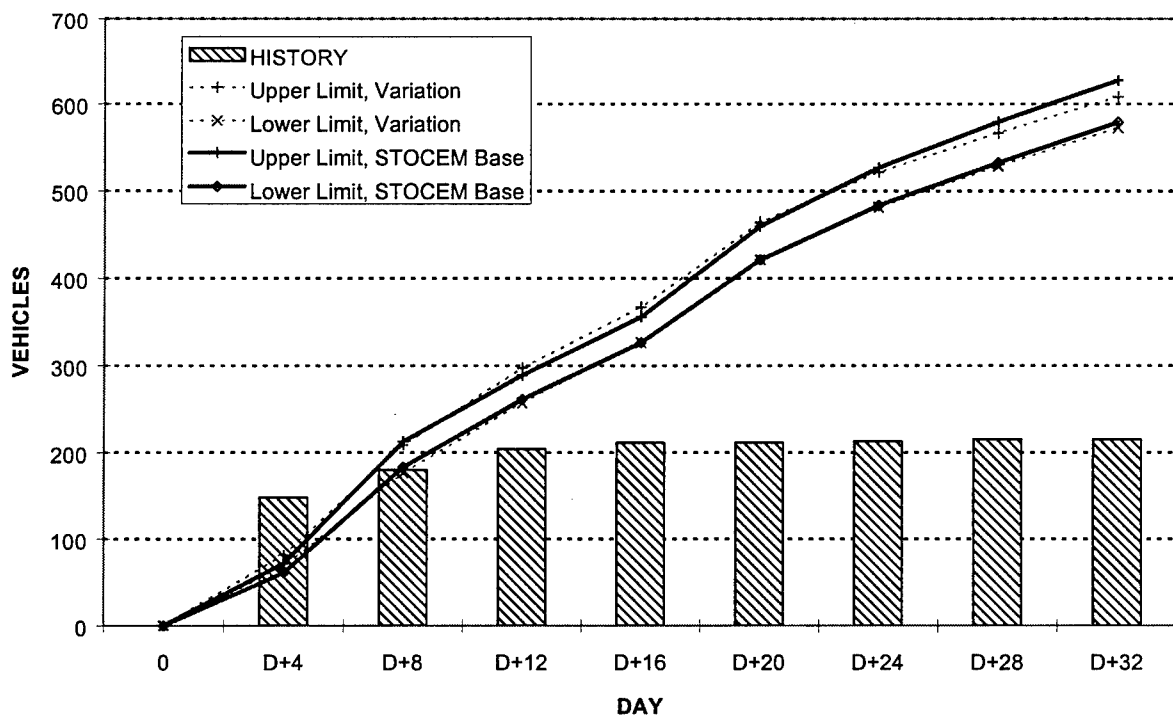
Figure 5-2. Cumulative Permanent Losses of US/UK Light Armor, Breakthrough/Overrun
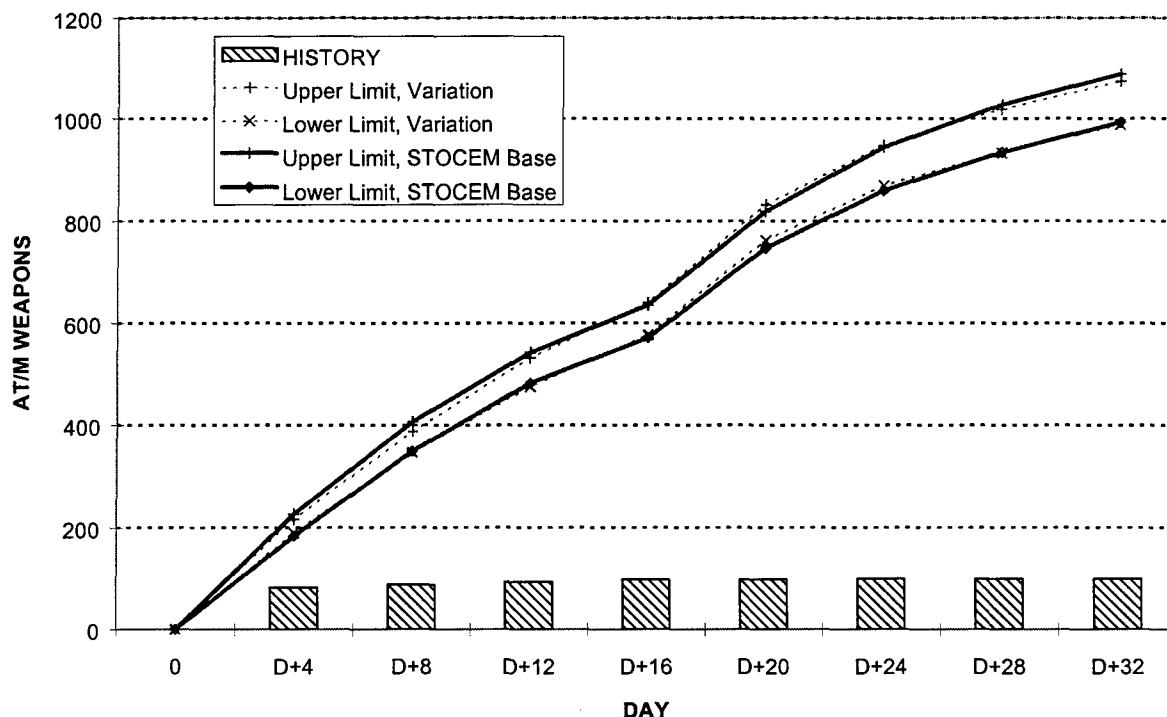
Figure 5-3. Cumulative Permanent Losses of US/UK Antitank/Mortars, Breakthrough/Overrun

(2) Figure 5-4 provides a comparison of the equipment losses of US/UK artillery between the base case results (solid lines enclosing confidence intervals) and the results of this STOCEM variation (dashed lines enclosing confidence intervals). Confidence intervals are defined as in previous chapters. Historical US/UK artillery losses are shown in Figure 3-6. This STOCEM variation exhibits a modest increase in US/UK attrition due to a few artillery positions being overrun by the German attackers in this variation. However, the quantity of US/UK artillery losses remains negligible compared to the historical losses (145 weapons by D+8). In order for the breakthrough/overrun modification of STOCEM to yield US/UK artillery losses as large as the historical losses, without changing the COSAGE/ATCAL combat attrition samples, the STOCEM computer routines might be modified to cause a fraction of the undamaged artillery of each overrun unit to be permanently lost. However, it would be difficult to justify such a change for artillery unless it applies to all equipment of an overrun unit. Such a change may be inappropriate for modern artillery, which is mostly self-propelled and located at a distance from the FEBA, so the artillery can escape being overrun.

Figure 5-4. Cumulative Permanent Losses of US/UK Artillery, Breakthrough/Overrun

b. **German Equipment Losses.** Figures 5-5 to 5-8 provide a comparison of the equipment losses of German tanks, light armor, antitank/mortars, and artillery, respectively, among the historical results (bars), the STOCEM base case results (solid lines enclosing confidence intervals), and the results of this STOCEM variation (dashed lines enclosing confidence intervals). In this variation, German losses of tanks, light armor, and artillery increase over the STOCEM base case in the second half of the simulated campaign. This indicates that counterattacking US/UK forces have sufficient strength in some sectors to satisfy the breakthrough criterion, thereby advancing quickly enough in this variation to cause German units in those sectors to abandon significantly more repairable damaged equipment than in the base case. One reason the losses of antitank/mortars (Figure 5-7) change very little from the STOCEM base case to this variation is that antitank/mortars in STOCEM do not suffer greater attrition in breakthrough sectors, as presently modeled.

Figure 5-5. Cumulative Permanent Losses of German Tanks, Breakthrough/Overrun
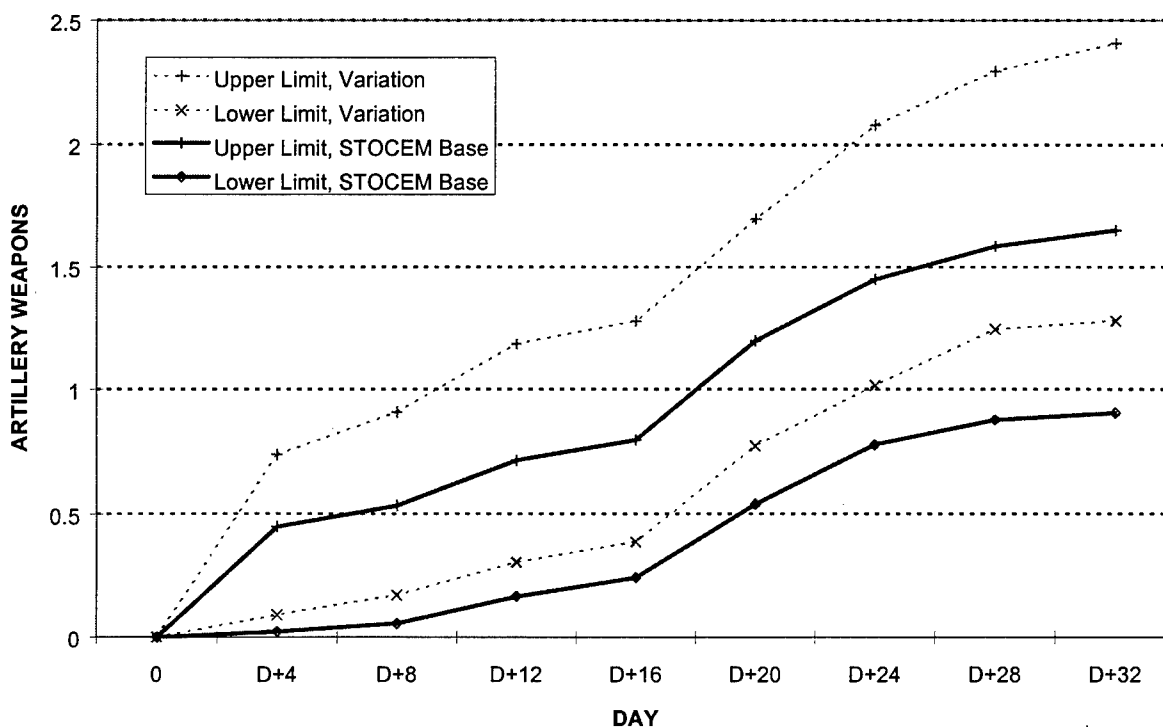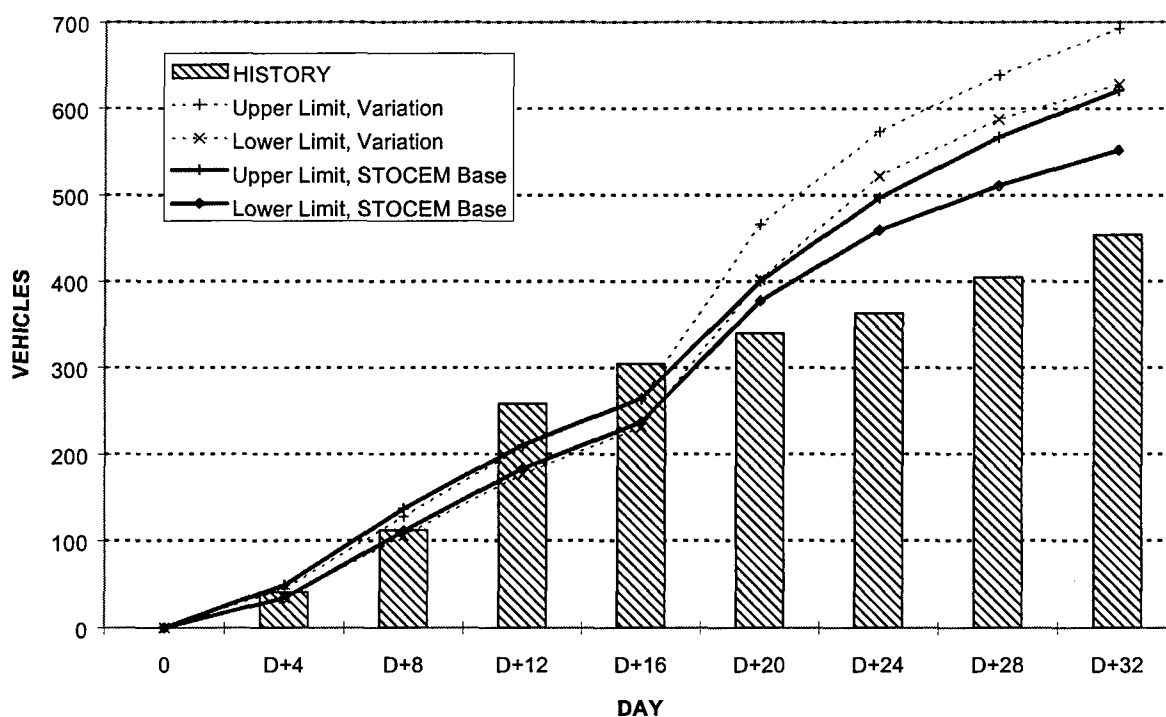

**Figure 5-6. Cumulative Permanent Losses of German Light Armor,
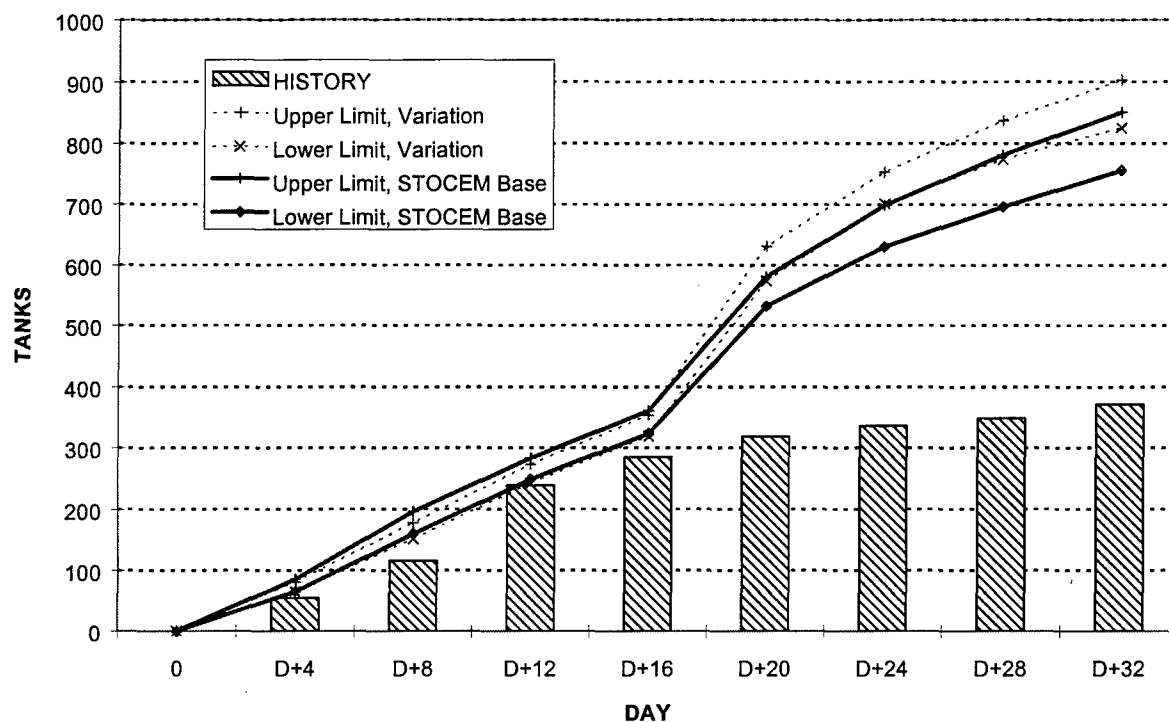Breakthrough/Overrun**
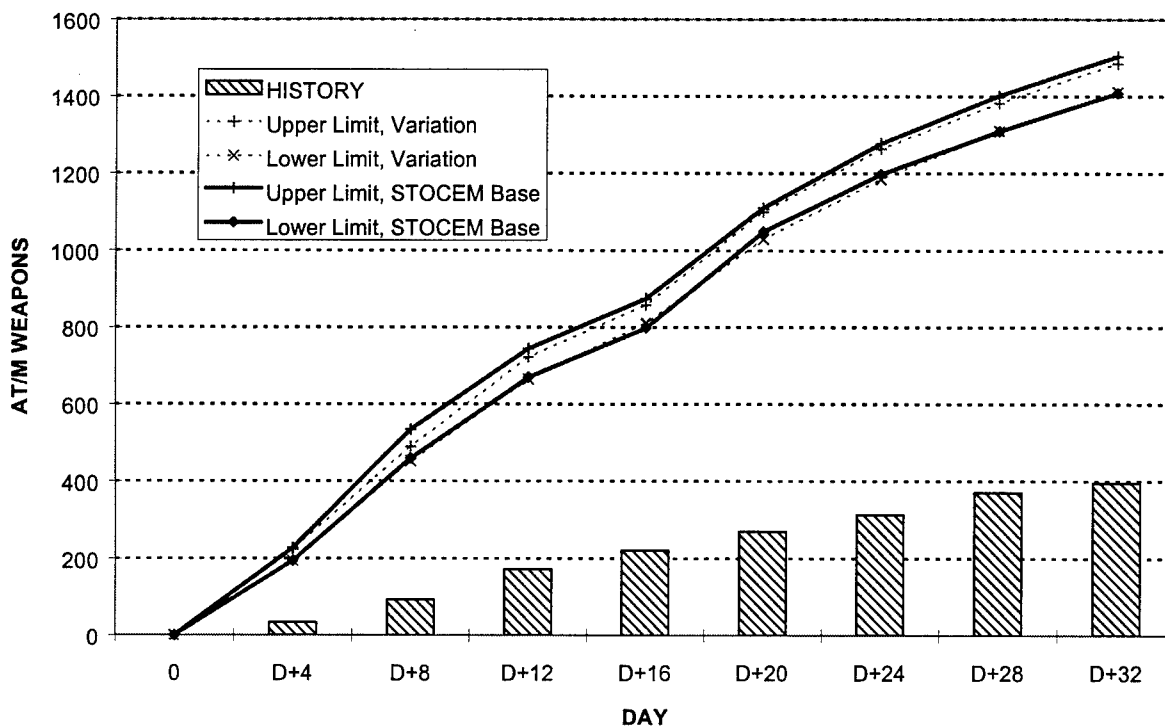
Figure 5-7. Cumulative Permanent Losses of German Antitank/Mortars, Breakthrough/Overrun

Figure 5-8. Cumulative Permanent Losses of German Artillery, Breakthrough/Overrun

c. **FEBA Locations.** Figures 5-9 and 5-10 display over a map at D+8 and D+20, respectively, the location of the historical FEBA, as calculated by ARCAS (solid dark line), the average of the 16 replications of the STOCEM base case (dashed dark line), and the average of the 16 replications of this STOCEM variation (white line). We observe from Figure 5-9 that German forces advance farther by D+8 in this variation than in the STOCEM base case or the historical Ardennes Campaign, because of the higher rate of advance in breakthrough sectors in this STOCEM variation.

Figure 5-9. D+8 FEBA Locations: History, Base Case, and Breakthrough/Overrun
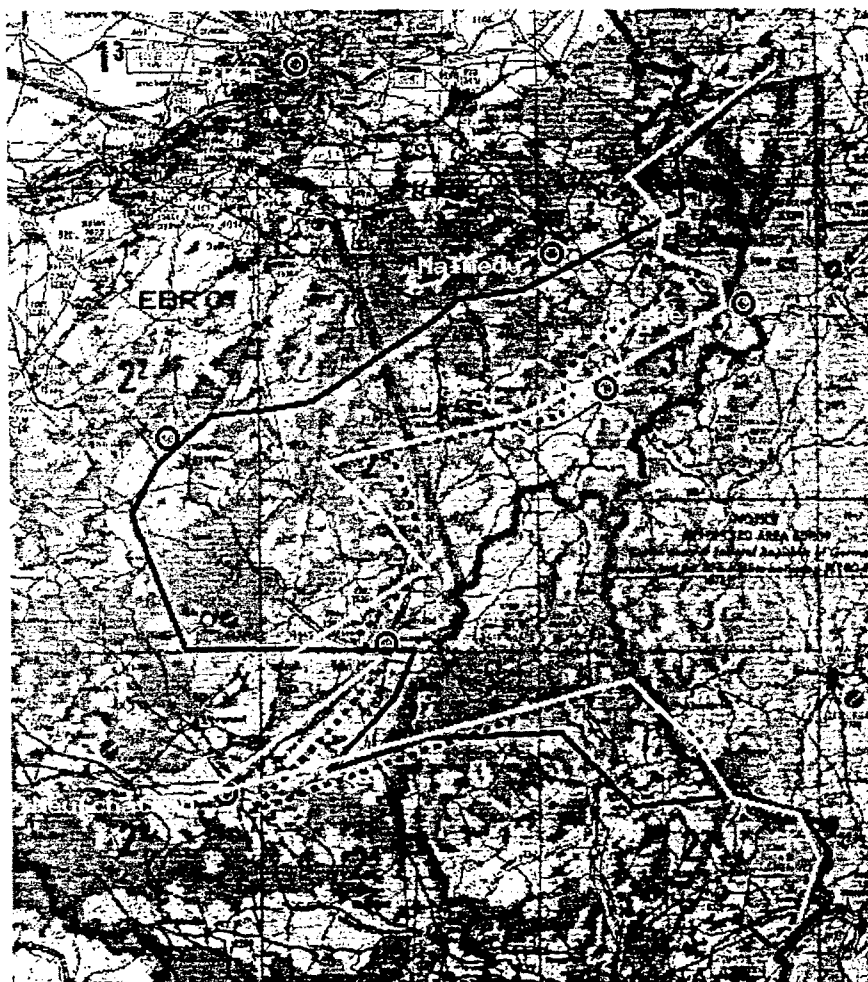
Figure 5-10. D+20 FEBA Locations: History, Base Case, and Breakthrough/Overrun

d. Personnel Losses. Figures 5-11 and 5-12 provide a comparison of the US/UK and German permanent personnel losses, respectively, among the historical results (bars), base case results (solid lines enclosing confidence intervals), and the results of this STOCEM variation (dashed lines enclosing confidence intervals). US/UK permanent personnel losses--dead, captured, missing, and patients requiring evacuation from theater--in this variation increased slightly from the STOCEM base case due to increased CMIA in the sectors of German breakthrough/overrun in the first half of the simulation of this STOCEM variation. German permanent personnel losses in this variation increased from the STOCEM base case in the second half of the simulated campaign. This confirms that counterattacking US/UK forces have sufficient strength in some sectors to satisfy the breakthrough criterion, thereby causing more German CMIA in those sectors than in the base case. The outcome makes the German casualties of this variation significantly further from the historical results than were those of the STOCEM base case.
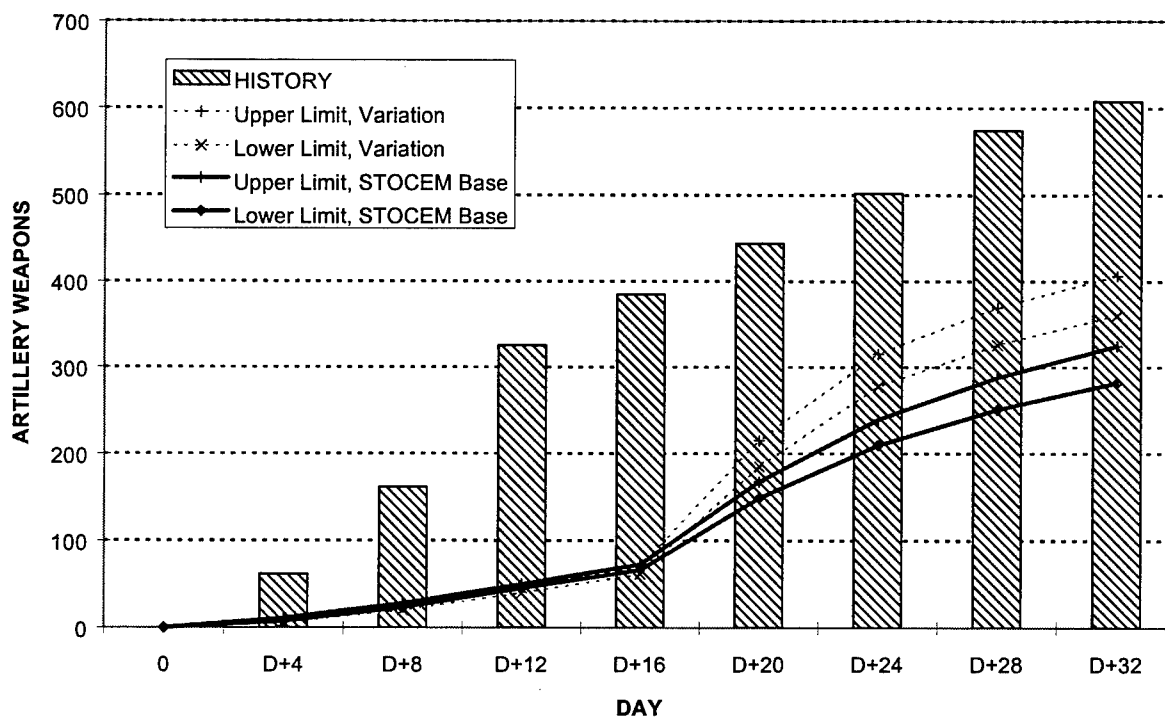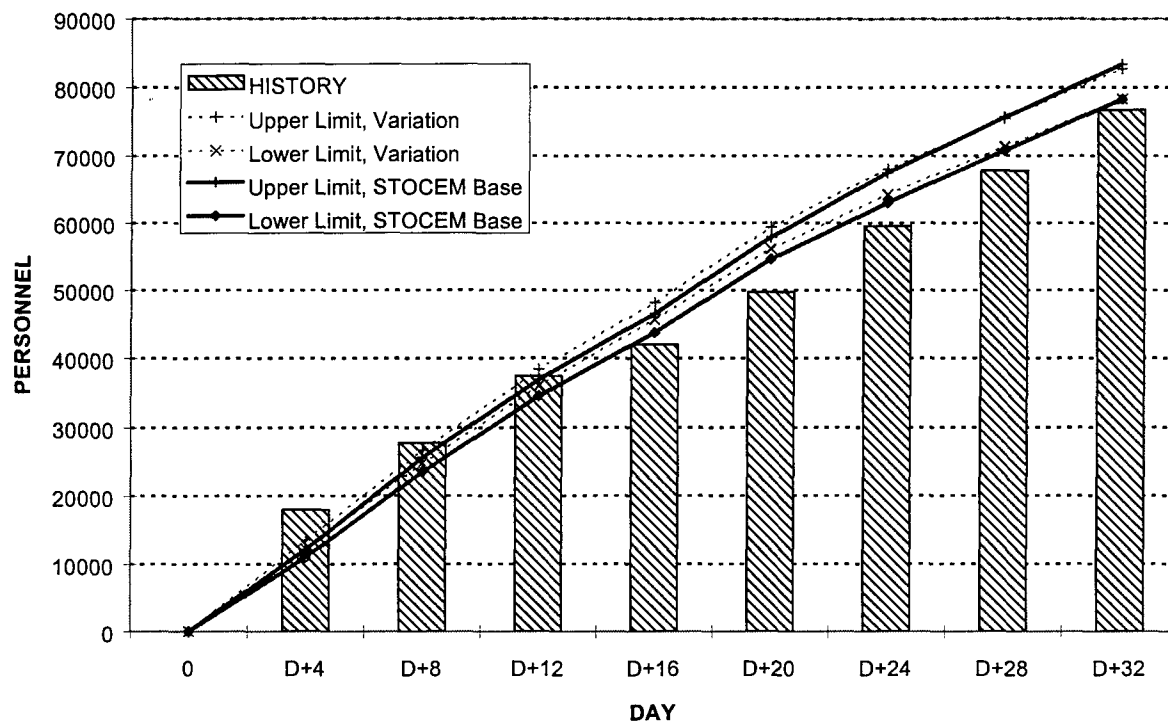
Figure 5-11. Cumulative Permanent Losses of US/UK Personnel, Breakthrough/Overrun
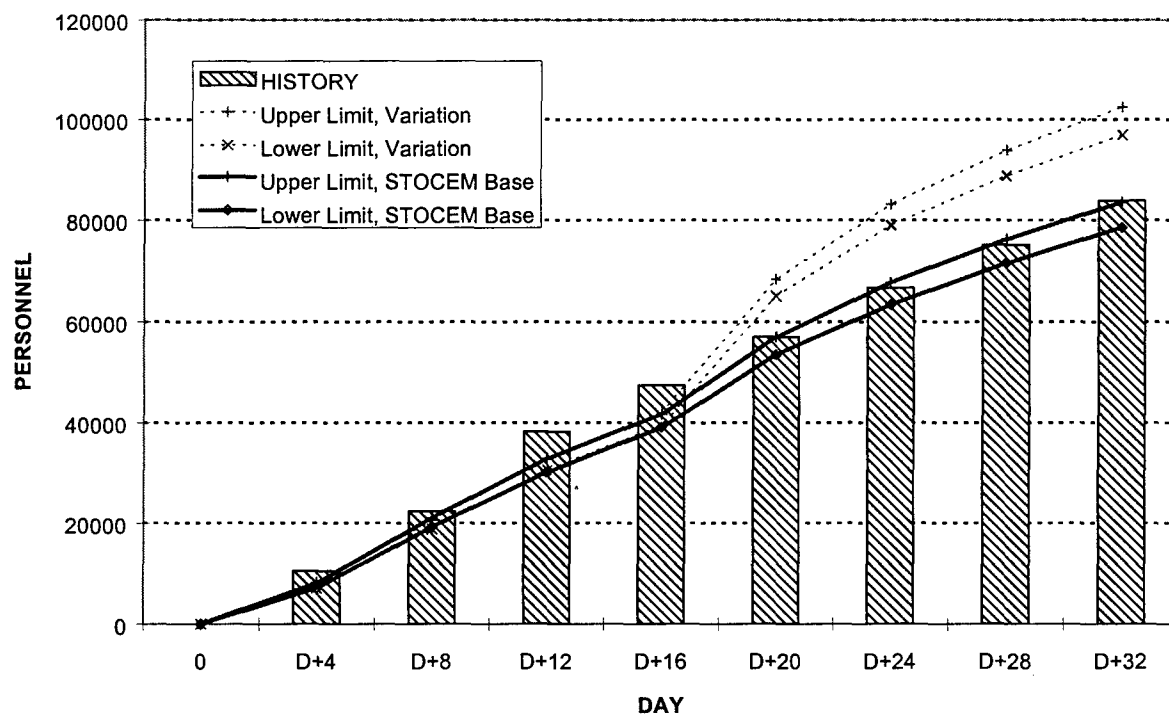
Figure 5-12. Cumulative Permanent Losses of German Personnel, Breakthrough/Overrun

e. Types of US/UK Casualties. Part of the ARCAS rationale for a STOCEM representation of breakthrough/overrun was that significantly smaller fractions of US/UK casualties in STOCEM were CMIA than in historical results. The STOCEM modeling of breakthrough/overrun in this variation causes greater numbers of CMIA among the defenders in the overrun sectors than in normal STOCEM attrition. Figures 5-13 to 5-16 provide a comparison of the fractions of daily US/UK casualties that are KIA, WIA, CMIA, and DNBI, respectively, among the historical results (bars), base case results (solid lines enclosing confidence intervals), and the results of this STOCEM variation (dashed lines enclosing confidence intervals). As expected, the fraction captured or missing increases in the first 4 days of this variation from the STOCEM base case, while the fraction wounded decreases.
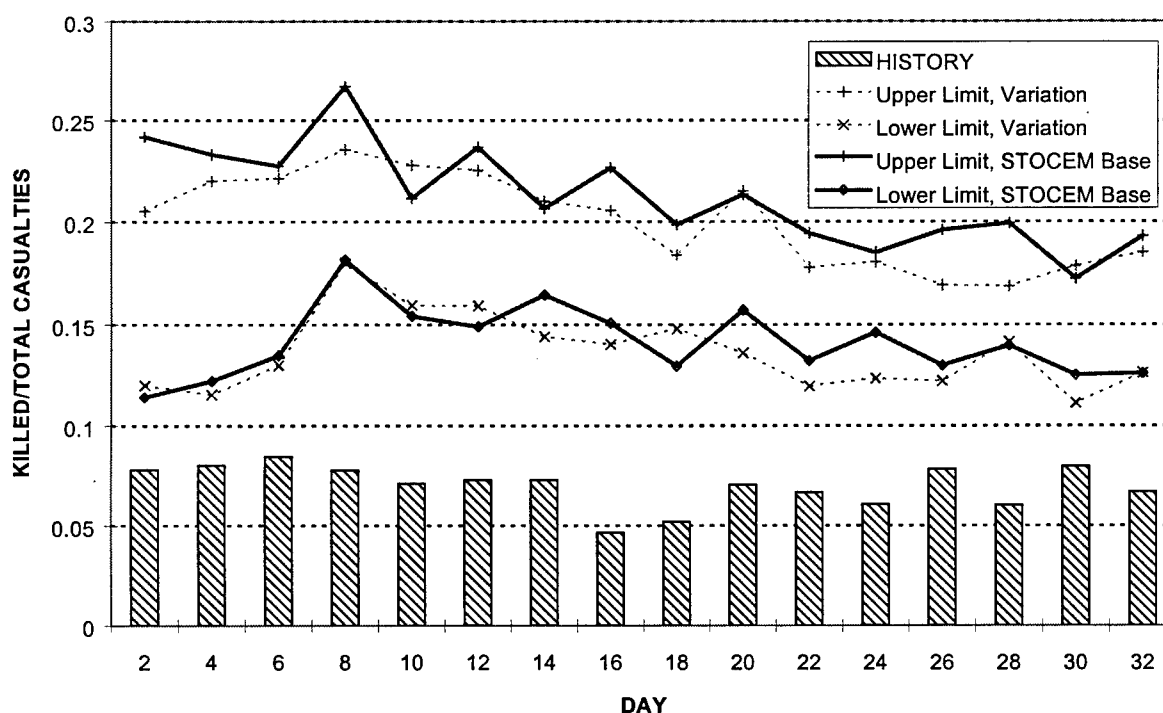
Figure 5-13. Fraction of US/UK Casualties that are Killed, Breakthrough/Overrun
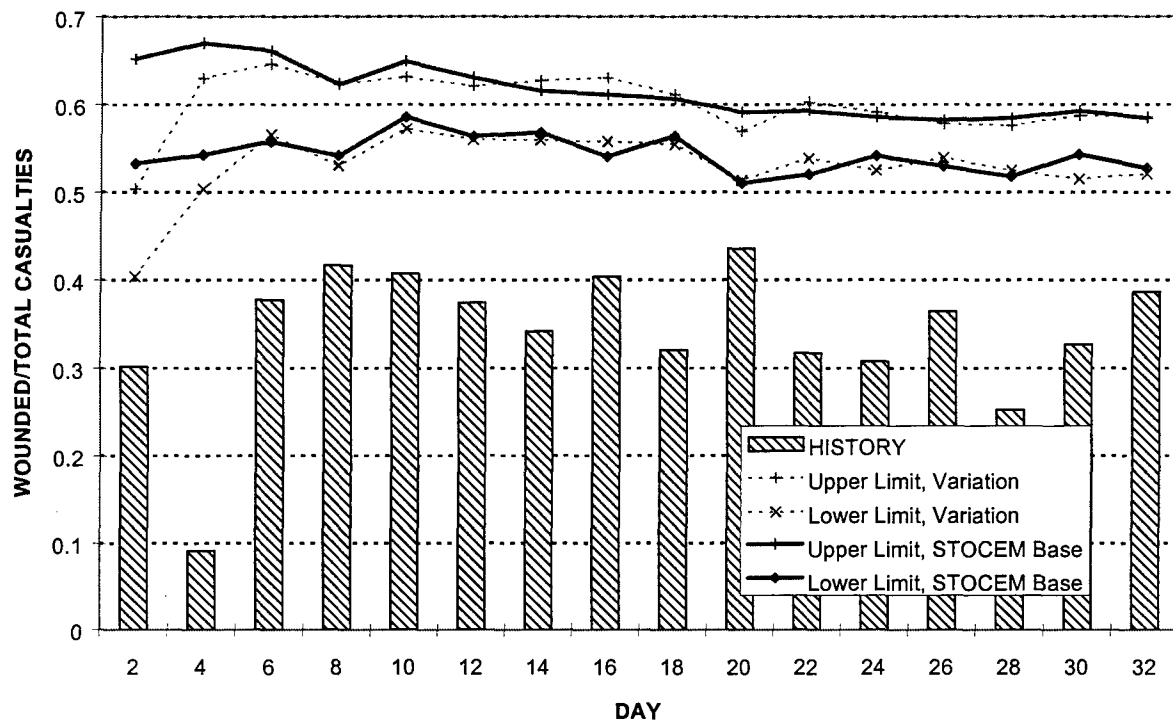
Figure 5-14. Fraction of US/UK Casualties that are Wounded, Breakthrough/Overrun
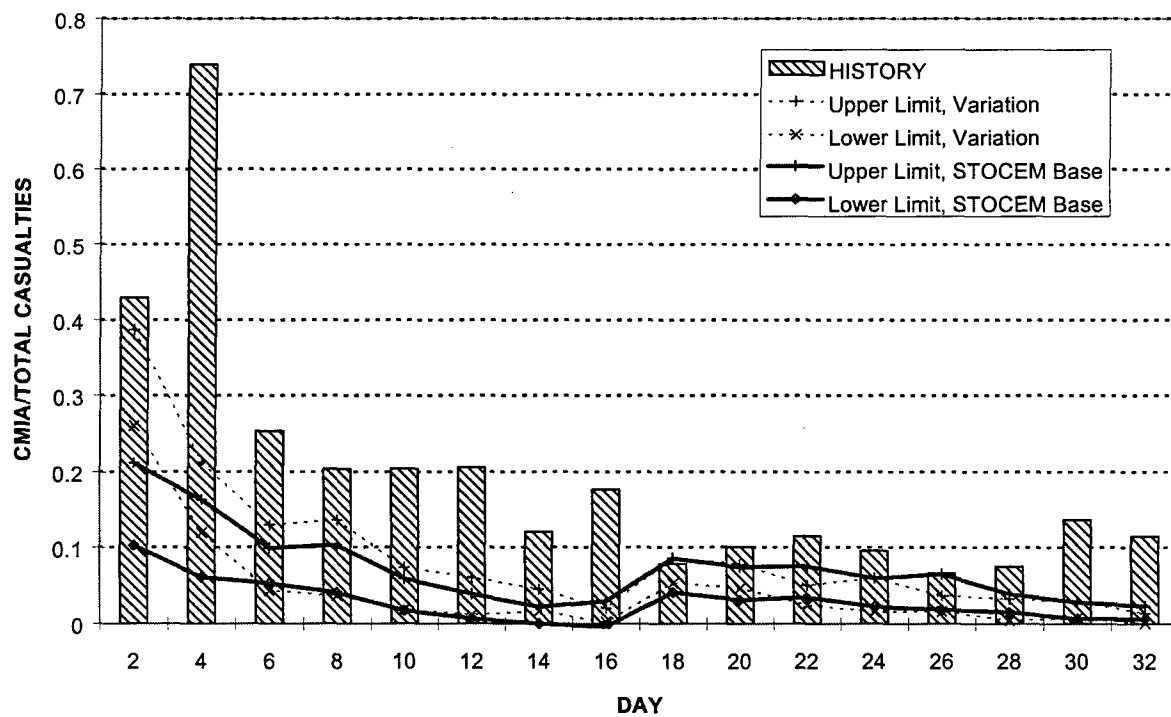
Figure 5-15. Fraction of US/UK Casualties that are Captured/Missing, Breakthrough/Overrun
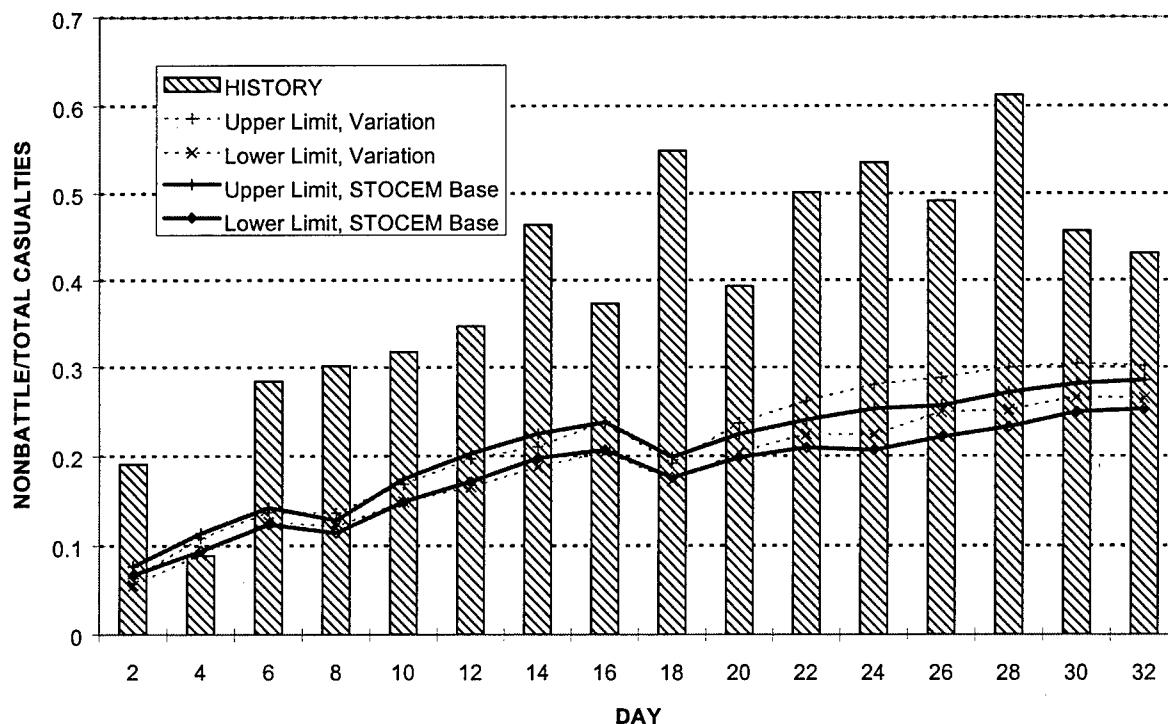
Figure 5-16. Fraction of US/UK Casualties that are DNBI, Breakthrough/Overrun

5-3. OBSERVATIONS

a. The results of this chapter indicate that the breakthrough/overrun modification of STOCEM affects the attrition of German equipment and personnel more than it affects US/UK attrition. The increase in attrition of German equipment and personnel in this variation from the STOCEM base case, in the second half of the campaign, is significant. This indicates that counterattacking US/UK forces have sufficient strength in some sectors to satisfy the break-through criterion, thereby causing German units in those sectors to suffer greater permanent losses, including abandoned equipment and captured/missing personnel, in this variation than in the base case.

b. In this breakthrough/overrun variation of STOCEM, the US/UK CMIA losses, as a fraction of total personnel casualties, are significantly higher in the first 4 days than the CMIA of the STOCEM base case. Conversely in this STOCEM variation, the US/UK WIA losses, as a fraction of total personnel casualties, are significantly lower in the first 4 days than the WIA of the STOCEM base case. Hence the types of US/UK casualties in the first 4 days simulated are closer to historical results than the STOCEM base case results were.

c. The ability of a STOCEM user to represent breakthrough and overrun by units with sufficient superiority in a sector is a useful improvement to our campaign simulation capability, because it allows model users to represent situations that may realistically occur in combat. Providing this greater flexibility to model users is always worthwhile, even if the model users elect not to use the breakthrough/overrun feature in a particular scenario.

d. Along with the ability to represent breakthrough and overrun comes the requirement for STOCEM users to select an appropriate force ratio threshold for breakthrough to occur and to estimate the fraction of uninjured personnel that become CMIA among the defenders in an overrun sector. We tried other levels of the force ratio threshold for breakthrough before selecting the value, 6.0, reported in this chapter. Higher threshold values leave the results of the first half of the campaign essentially the same as the STOCEM base case. Lower thresholds result in German forces advancing substantially beyond the historical FEBA by D+8.

e. The US forces that surrendered in large numbers, such as the 106th Infantry Division in the Ardennes Campaign, tended to be inexperienced and inadequately trained. Training and combat experience are among many human factors that STOCEM does not model. In order to increase the likelihood that units overrun in STOCEM are the same units overrun in the historical Ardennes Campaign, STOCEM could be modified to represent human factors. However, the Ardennes Campaign Simulation Data Base does not presently contain data to support the representation of human factors. The combined effect on military performance of human factors such as combat experience, training, morale, leadership, etc., is difficult to quantify objectively, and this effect does not remain constant over time. Some human factors enter STOCEM through the COSAGE/ATCAL process when we distinguish between the performance of the same weapon type operated by personnel of different nationalities, but this does not allow us to distinguish between individual units of the same nationality. The application in STOCEM of human factors, to distinguish between the capabilities of individual units of the same nationality, would require model users to assign subjectively a "human factor" to each unit of each side. This human factor would be used to degrade or enhance some aspects of the units' performance in the combat engagements modeled in STOCEM.

f. The modification of STOCEM described in this chapter captures the main effects of breakthrough/overrun, but the modeling of breakthrough/overrun could be refined considerably. For example, the effects of breakthrough/overrun on attrition of equipment, ammunition, and supplies and on disruption of rear area logistics might be represented with more fidelity. Methods of representing breakthrough and payoffs for penetrations in CEM were examined in some detail by CAA in Reference 7, but the CEM modifications of Ref. 7 were not adopted.

CHAPTER 6

TYPES OF PERSONNEL CASUALTIES

6-1. RECOMMENDATION OF ARCAS

a. ARCAS found that, "for the US/UK force, the STOCEM-processed average KIA fraction and WIA fraction are almost double the corresponding history values. The STOCEM average CMIA fraction is almost a third of the corresponding historical value, while the STOCEM average DNBI fraction is most half of the corresponding historical value" (Ref. 1, p 7-3). Consequently "redistribution of STOCEM casualties over the four casualty types appears appropriate and necessary" (Ref. 1 p 7-7).

b. In response to this recommendation, we adjusted the STOCEM inputs that affect the types of personnel casualties. User inputs to STOCEM establish the fraction of onhand personnel that become nonbattle casualties every 12 hours. Other user inputs determine, by STOCEM posture, the fractions of *combat casualties* that are KIA, WIA, and CMIA. The values of these input factors used in the STOCEM base case and ARCAS have been used in many CAA analyses. The quantity of combat casualties in each STOCEM engagement is a product of the COSAGE/ATCAL attrition process

6-2. STOCEM SIMULATIONS. The simulations we report using this STOCEM modification were executed with an input of 3.00 nonbattle losses (DNBI) per hundred personnel per half day, in place of the 2.16 used in the STOCEM base case. Also, the fraction of combat casualties KIA were reduced from the base case for some postures, so that the fraction of combat casualties CMIA would be at least 0.10 in the US/UK attack postures and 0.20 for the German attack postures in this STOCEM variation. KIA and CMIA are both treated as permanent losses in STOCEM. The fraction of combat casualties wounded was not adjusted, and the COSAGE/ATCAL attrition inputs that determine total combat casualties were not adjusted. Sixteen replications of STOCEM were executed for this case, as in the STOCEM base case and in ARCAS.

6-3. US/UK PERSONNEL LOSSES. Figure 6-1 provides a comparison of the US/UK permanent personnel losses among the historical results (bars), base case results (solid lines enclosing confidence intervals), and the results of this STOCEM variation (dashed lines enclosing confidence intervals). US/UK permanent personnel losses--dead, captured, missing, and patients requiring evacuation from theater--in this variation increase noticeably from the STOCEM base case, due to the increased DNBI of this variation, since some DNBI become permanent losses. The outcome makes the US/UK casualties of this variation further from the historical results than those of the STOCEM base case were.
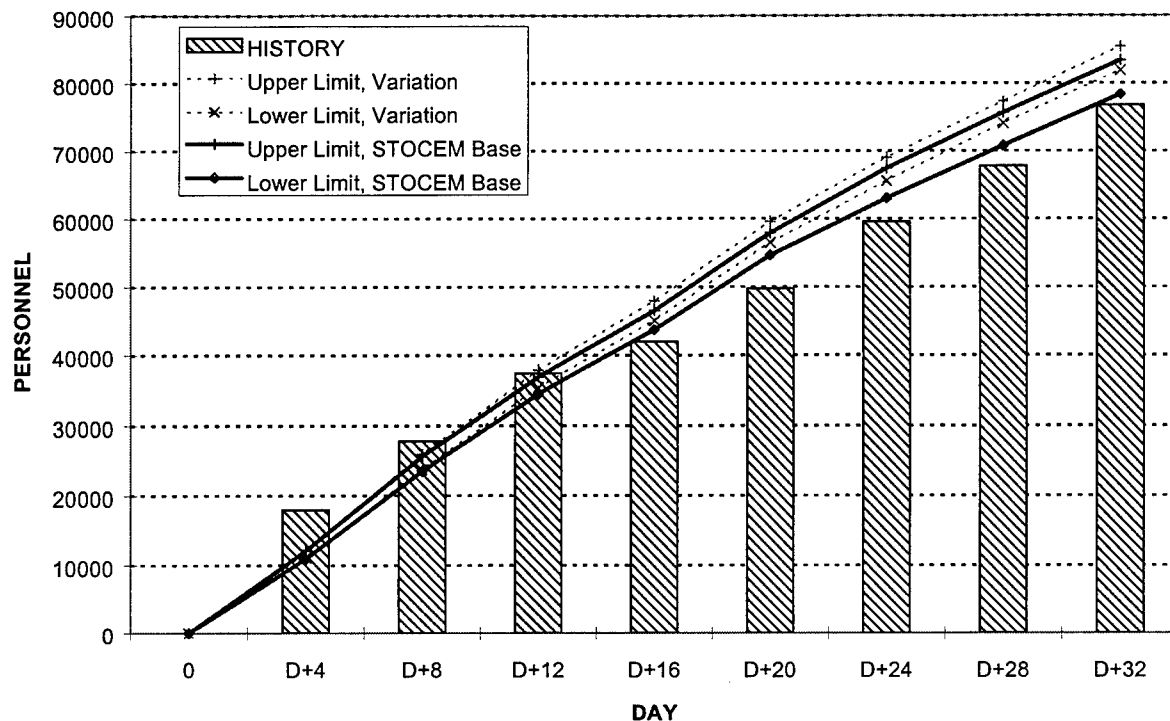
Figure 6-1. Cumulative Permanent Losses of US/UK Personnel, Increased CMIA and DNBI

6-4. TYPES OF US/UK CASUALTIES. The rationale for this STOCEM variation is that significantly smaller fractions of US/UK casualties in STOCEM were CMIA and DNBI than in historical results. The STOCEM inputs adjusted in this variation cause greater numbers of CMIA and DNBI than in the STOCEM base case. Figures 6-2 to 6-5 provide a comparison of the fractions of daily US/UK casualties that are KIA, WIA, CMIA, and DNBI, respectively, among the historical results (bars), base case results (solid lines enclosing confidence intervals), and the results of this STOCEM variation (dashed lines enclosing confidence intervals). As expected, the fraction nonbattle losses (DNBI, Figure 6-5) and fraction captured or missing (Figure 6-4) increase in this variation from the STOCEM base case, while the fraction killed (Figure 6-2) decreases from the STOCEM base case. The fraction wounded (Figure 6-3) decreases slightly because DNBI constitutes a larger fraction of total casualties in this variation than in the STOCEM base case, making combat casualties, including WIA, a smaller fraction of the total casualties than in the STOCEM base case. All four types of casualties, as fractions of the total casualties, are closer to the historical results than are the fractional types of the STOCEM base case.
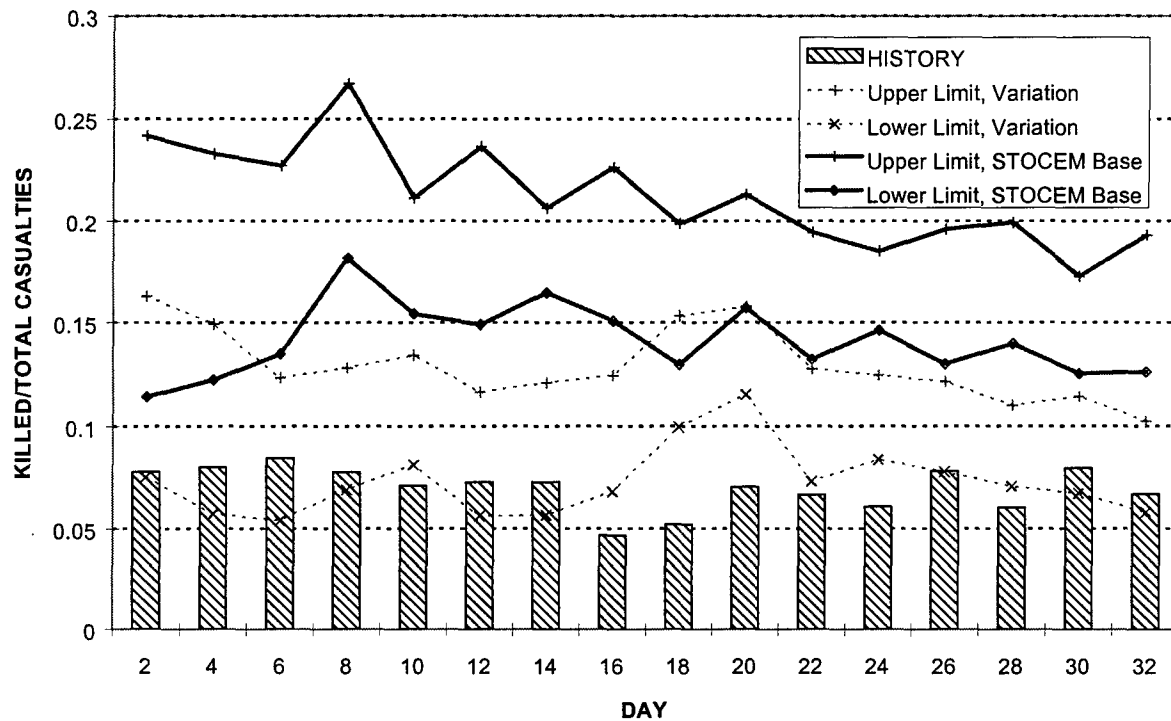
Figure 6-2. Fraction of US/UK Casualties that are Killed, Increased CMIA and DNBI
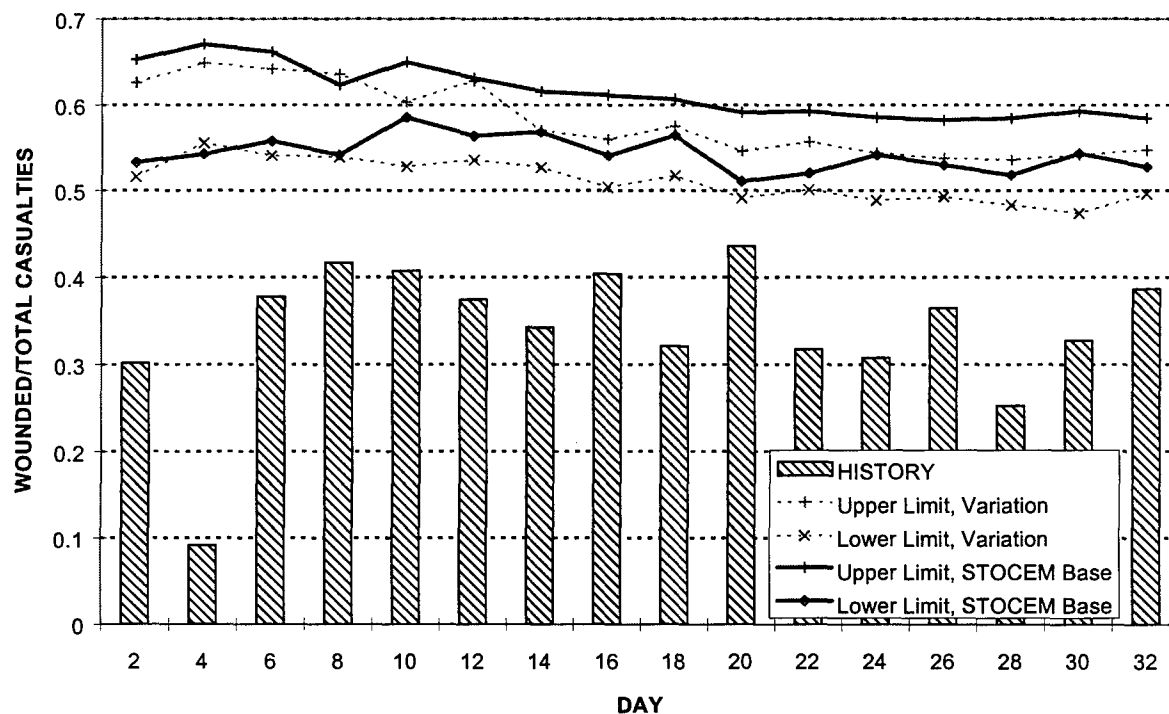
Figure 6-3. Fraction of US/UK Casualties that are Wounded, Increased CMIA and DNBI
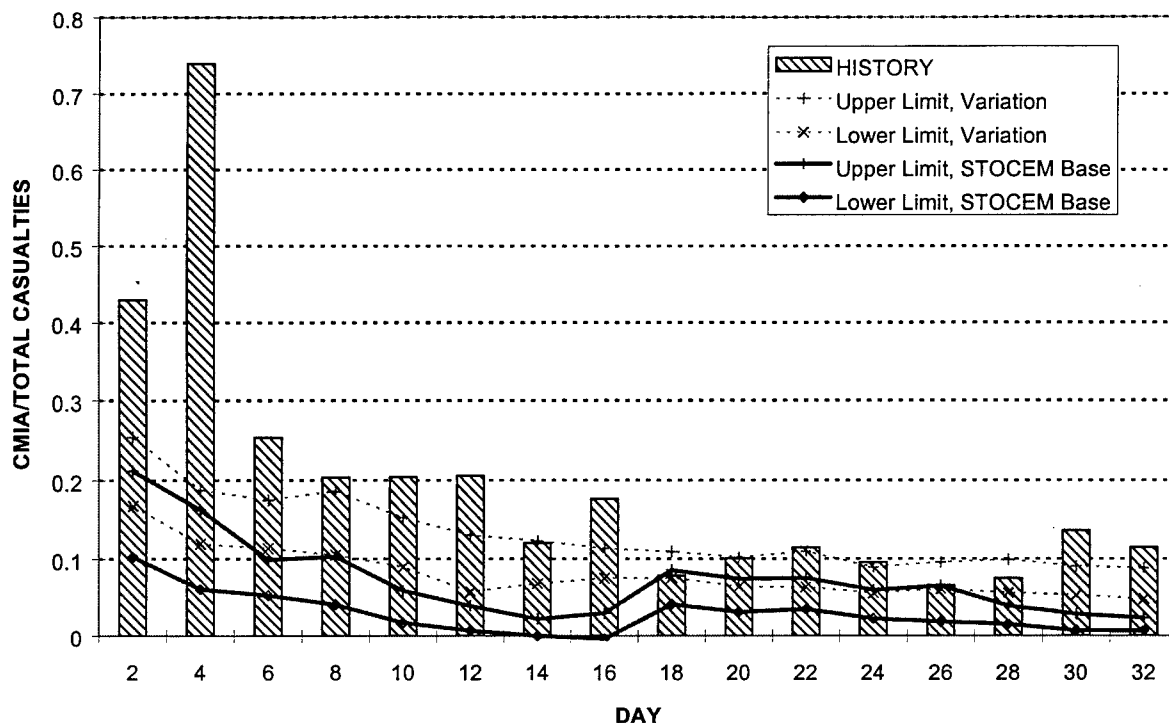
Figure 6-4. Fraction of US/UK Casualties that are Captured/Missing, Increased CMIA and DNBI
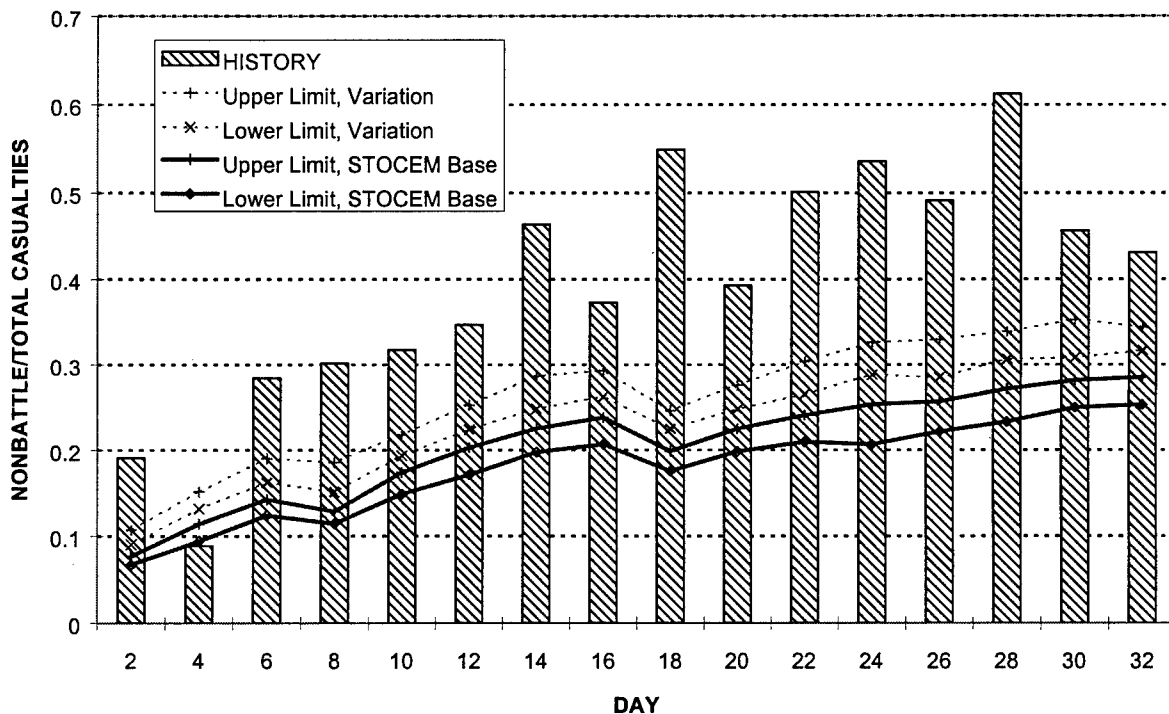
Figure 6-5. Fraction of US/UK Casualties that are DNBI, Increased CMIA and DNBI

6-5. OBSERVATIONS

a. The results of this chapter indicate that the adjustment of appropriate STOCEM inputs can bring the resulting KIA, WIA, CMIA, and DNBI fractions of US/UK personnel casualties into closer agreement with history than are the STOCEM base case results.

b. However, these STOCEM input adjustments also cause the US/UK permanent personnel losses to increase from the STOCEM base case. This STOCEM variation produces permanent losses of US/UK personnel that are further from historical results than are the STOCEM base case results. It appears that the adjustment of inputs to STOCEM cannot bring the permanent losses and the KIA, WIA, CMIA, and DNBI fractions of total casualties into close agreement, unless the total *combat casualties* are decreased in STOCEM. Reduction of combat casualties would require either different COSAGE/ATCAL inputs with fewer personnel casualties or revised decision threshold inputs to STOCEM that would produce fewer attacks and hence fewer losses in STOCEM. Such changes to STOCEM inputs to reduce combat casualties of personnel could change other outcomes also, resulting in a significantly different campaign simulation.

CHAPTER 7

COMBINED STOCEM CHANGES

7-1. MODIFICATIONS OF STOCEM

a. In response to an ARCAS recommendation, STOCEM was modified to permit the representation of breakthrough/overrun whenever the attacking force in a STOCEM subsector achieves an overwhelming advantage in combat worth ratio. This modification is described in Chapter 5 of this report. User inputs to STOCEM establish the attacker/defender force ratio threshold above which breakthrough occurs and specify the fraction of the defending unit's personnel in the subsector that become captured/missing when the unit is overrun. In case of a breakthrough/overrun, all repairable damaged vehicles in the unit that is overrun in the subsector are abandoned and therefore permanently lost. All wounded and DNBI in the subsector of an overrun unit become CMIA. Also, in a breakthrough sector, the distance advanced by the attacker is calculated as if the attacker were unopposed, at the maximum rate for the terrain type; but STOCEM limits on the length of exposed flanks continue to apply in a breakthrough. Consumption of ammunition and losses of antitank/mortar weapons, which are not repairable in STOCEM, are not affected by this representation of breakthrough/overrun.

b. In response to another ARCAS recommendation, STOCEM was modified to permit the STOCEM user to specify by input the maximum duration, in 12-hour cycles, of a sustained attack by any maneuver unit. This modification is described in Chapter 4 of this report. The user now can specify the maximum number of consecutive 12-hour combat cycles a Blue brigade may continue attacking and, separately, the maximum number of consecutive 12-hour cycles a Red division may attack. When a Blue brigade or Red division has attacked for the number of consecutive cycles specified by input, that unit must assume a nonattack mission for at least 12 hours before attacking again.

c. The results reported in this chapter show the combined effects of both the above STOCEM modifications, as well as the other refinements included in the STOCEM base case.

7-2. STOCEM SIMULATIONS. The simulations we report using this STOCEM modification were executed with an input threshold of 6.0 for breakthrough; so breakthrough/overrun occurs whenever the attacker/defender combat worth ratio exceeds 6:1 in a STOCEM subsector. STOCEM inputs for these simulations specify that 10 percent of the overrun unit's uninjured personnel in the subsector become CMIA casualties. Limits of 24 hours were placed on the duration of attacks by each side in this STOCEM variation. Other STOCEM inputs are the same as in the STOCEM base case. Sixteen replications of STOCEM were executed for this case, as in the STOCEM base case and in ARCAS.

7-3. STOCEM RESULTS

a. UK Equipment Losses

(1) Figures 7-1 to 7-3 provide a comparison of the equipment losses of US/UK tanks, light armor, and antitank/mortars, respectively, among the historical results (bars), base case results (solid lines enclosing confidence intervals), and the results of this STOCEM variation (dashed lines enclosing confidence intervals). Confidence intervals are defined as in previous chapters, yielding greater than 99 percent confidence under the approximate normality assumptions of the Student-Fisher t-statistic, and at least 90 percent confidence without the normality assumptions. Figures 7-1, 7-2, and 7-3 show that US/UK tank and antitank/mortar losses in this variation decrease significantly, and light armor losses also decrease slightly from the STOCEM base case.
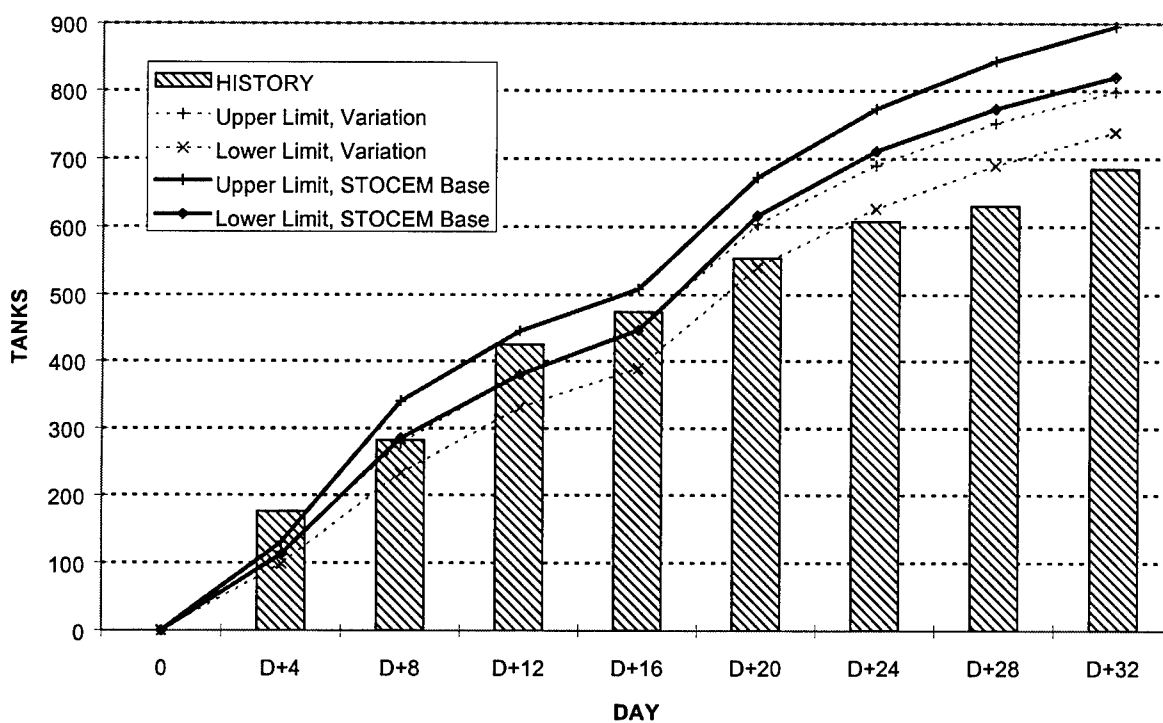
Figure 7-1. Cumulative Permanent Losses of US/UK Tanks, Breakthrough and 24-Hour Attack Limit
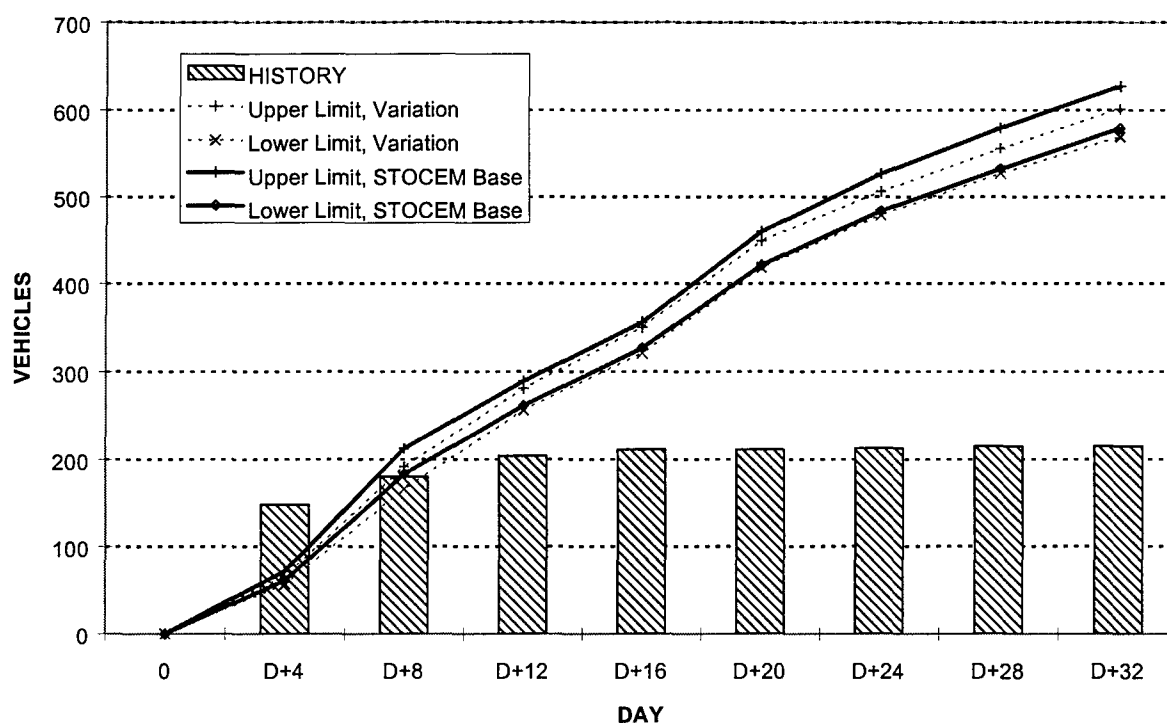
Figure 7-2. Cumulative Permanent Losses of US/UK Light Armor, Breakthrough and 24-Hour Attack Limit
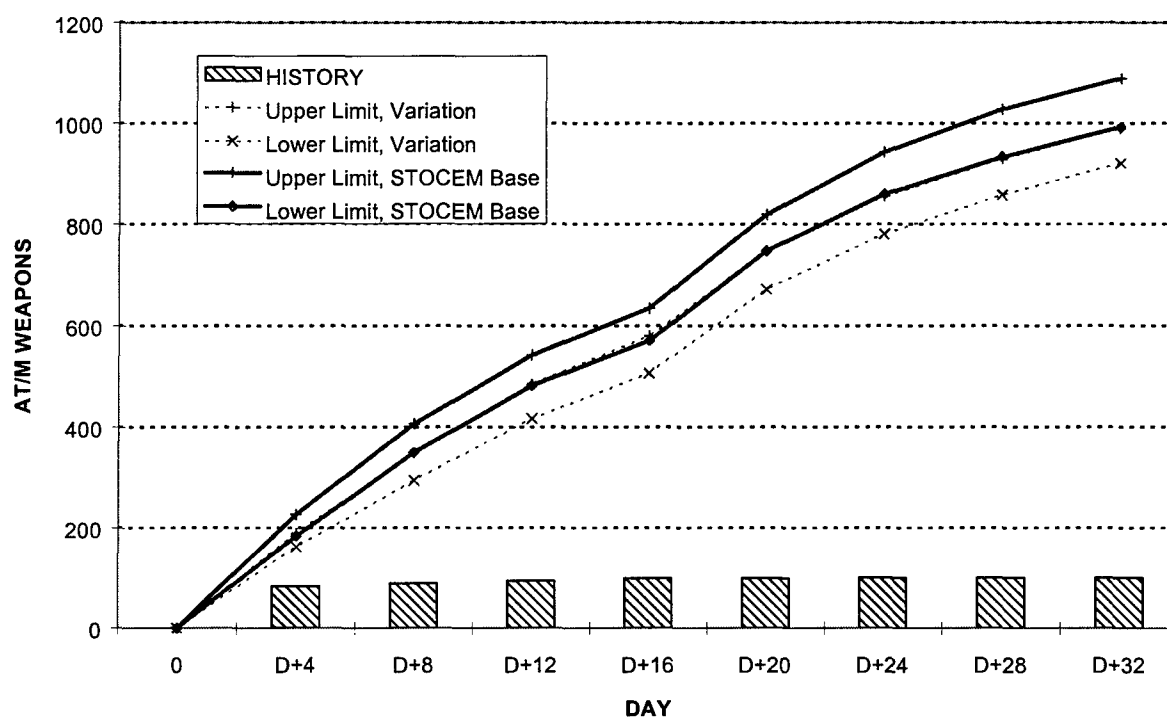
Figure 7-3. Cumulative Permanent Losses of US/UK Antitank/Mortars, Breakthrough and 24-Hour Attack Limit

(2) The losses of US/UK equipment decrease in this variation from the STOCEM base case because this variation permits a division to attack for only 24 hours at a time, so there are fewer divisions of both sides attacking in this variation than in the STOCEM base case. Figure 7-4 compares the percentages of US/UK units that are attacked, between the STOCEM base case (solid lines) and this variation (dashed lines). It is clear from Figure 7-4 that this variation reduces German attacks, particularly in the first 12 days of the campaign, from the STOCEM base case. Figure 7-5 compares the percentages of US/UK units in static posture (neither side attacking), between the STOCEM base case (solid lines) and this variation (dashed lines). The reduction in the number of attacks permitted in this STOCEM variation causes an increase from the STOCEM base case in the occurrences of static posture, which produces less attrition for both sides than does an attack by either side.
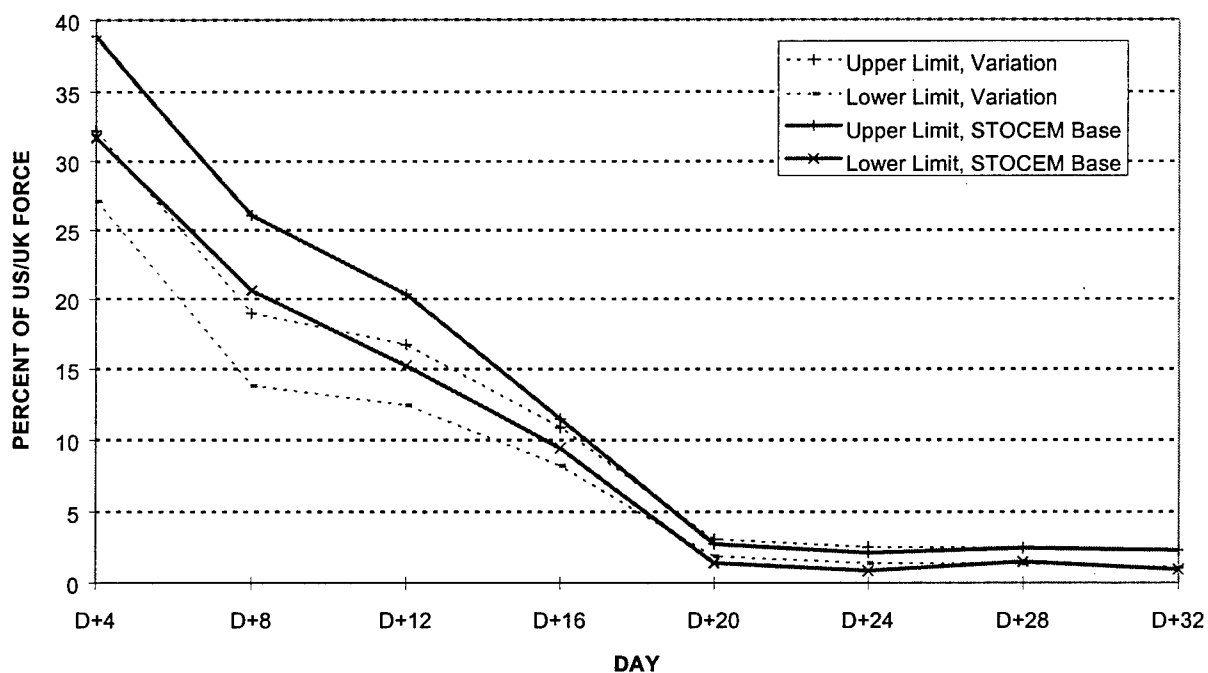
Figure 7-4. Frequency of German Attack, Breakthrough and 24-Hour Attack Limit

(3) Figure 7-6 provides a comparison of the equipment losses of US/UK artillery between the base case results (solid lines enclosing confidence intervals) and the results of this STOCEM variation (dashed lines enclosing confidence intervals). Confidence intervals are defined as in previous chapters. Historical losses of US/UK artillery are shown in Figure 3-6. This STOCEM variation exhibits a slight increase from the STOCEM base case through D+20 in losses of US/UK artillery, a consequence of German overruns of some sectors in this variation.

Figure 7-5. Frequency of Static Posture, Breakthrough and 24-Hour Attack Limit

Figure 7-6. Cumulative Permanent Losses of US/UK Artillery, Breakthrough and 24-Hour Attack Limit
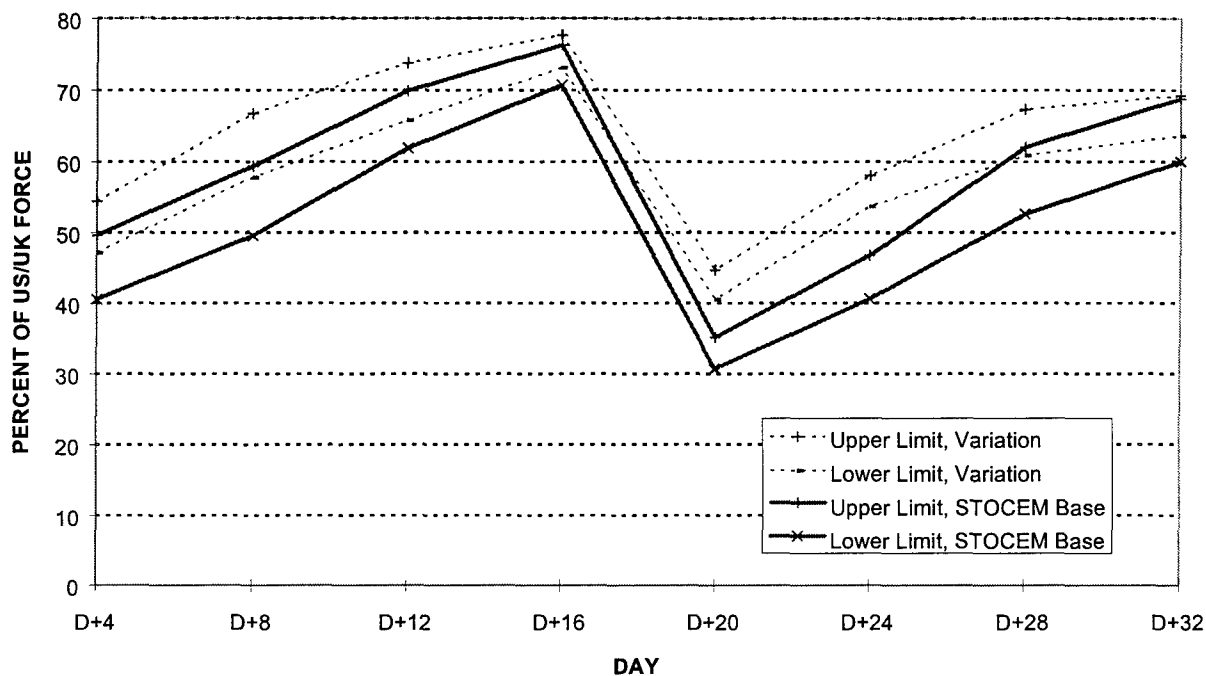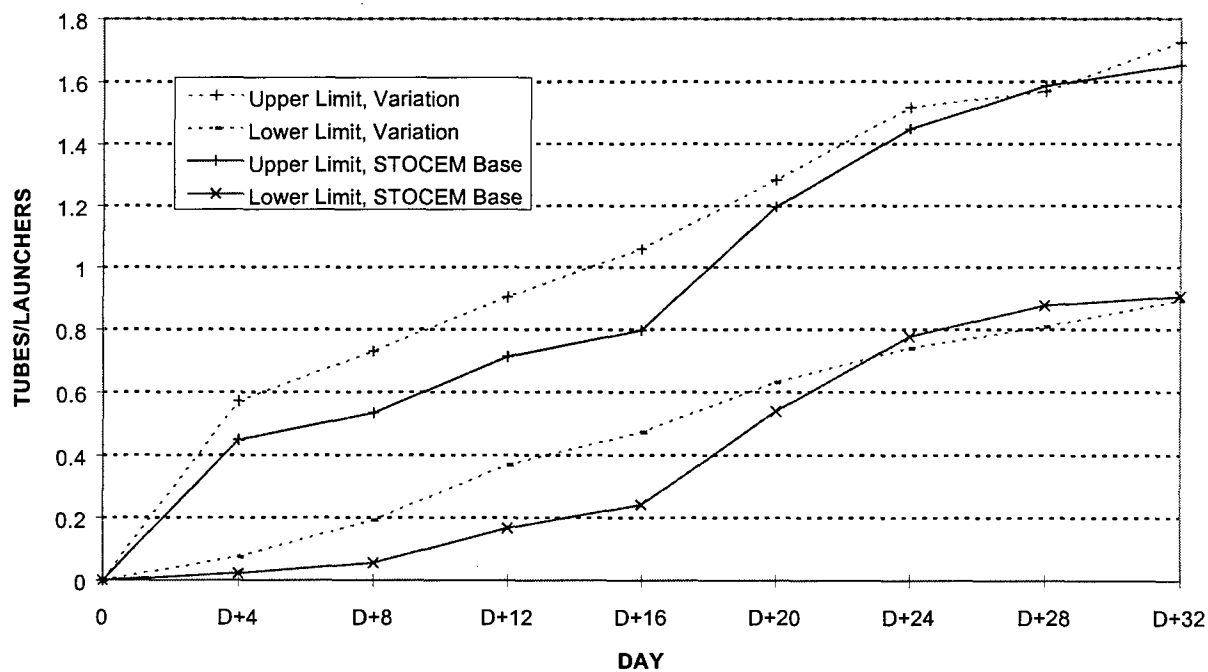
b. German Equipment Losses. Figures 7-7 to 7-10 provide a comparison of the equipment losses of German tanks, light armor, antitank/mortars, and artillery, respectively, among the historical results (bars), the STOCEM base case results (solid lines enclosing confidence intervals), and the results of this STOCEM variation (dashed lines enclosing confidence intervals). In this variation, German losses of tanks, light armor, and artillery increase over the STOCEM base case in the second half of the simulated campaign. This indicates that counterattacking US/UK forces have sufficient strength in some sectors to satisfy the breakthrough criterion, thereby advancing quickly enough in this variation to cause German units in those sectors to abandon significantly more repairable damaged equipment than in the base case. The losses of antitank/mortars (Figure 7-9) do not increase from the STOCEM base case to this variation because antitank/mortars in STOCEM do not suffer greater attrition in overrun units, as presently modeled. German losses of equipment decrease slightly from the STOCEM base case in the first 12 days of the simulation because of the reduction in the number of German attacks permitted in this STOCEM variation. The decrease in German attacks in the early days of this STOCEM variation causes an increase from the STOCEM base case in the occurrences of static posture, which produces less attrition for both sides than the German attack posture does.
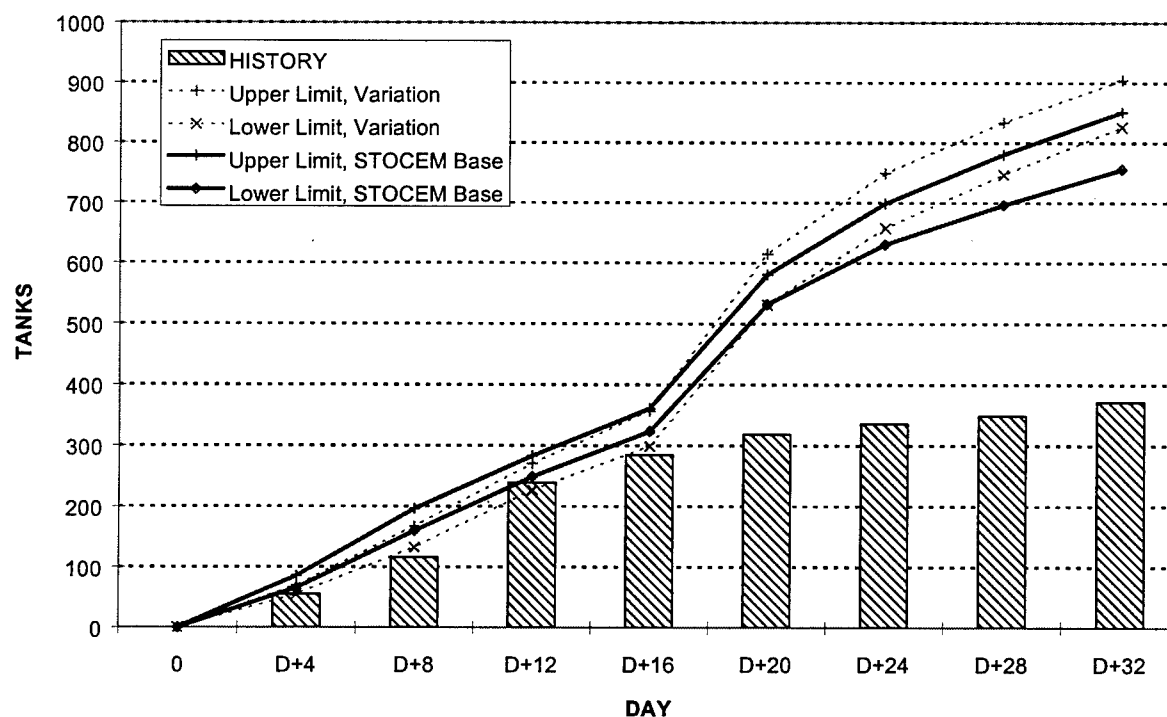
Figure 7-7. Cumulative Permanent Losses of German Tanks, Breakthrough and 24-Hour Attack Limit
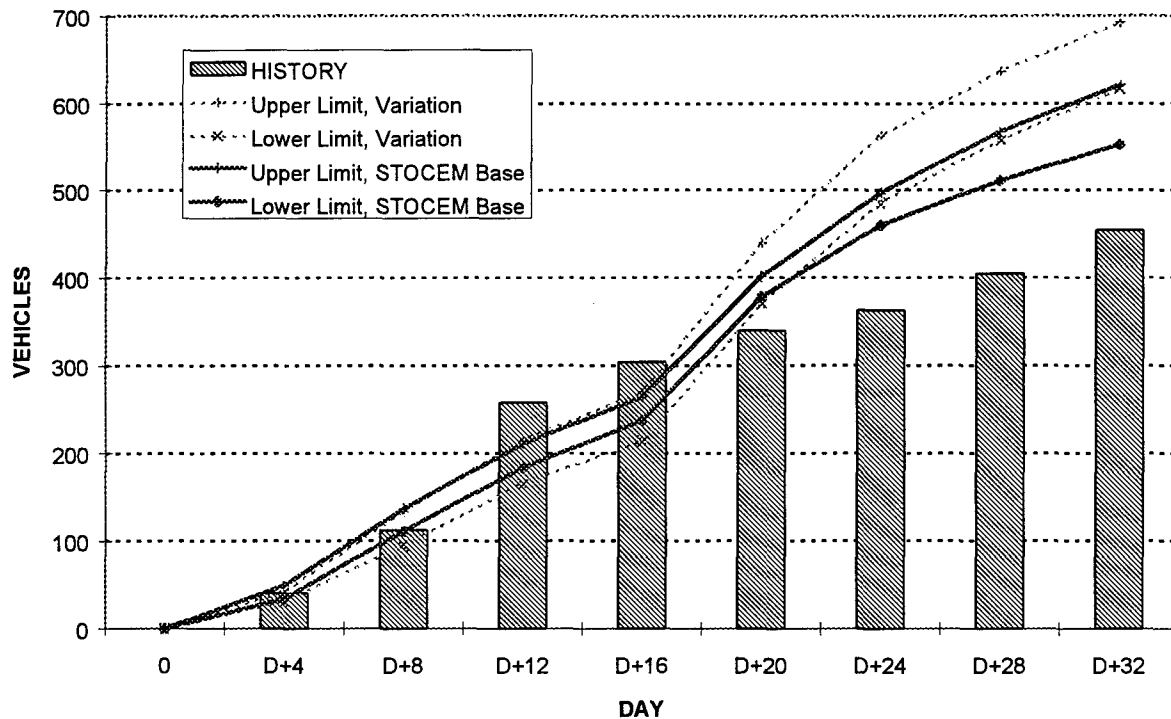
Figure 7-8. Cumulative Permanent Losses of German Light Armor, Breakthrough and 24-Hour Attack Limit

Figure 7-9. Cumulative Permanent Losses of German Antitank/Mortars, Breakthrough and 24-Hour Attack Limit

Figure 7-10. Cumulative Permanent Losses of German Artillery, Breakthrough and 24-Hour Attack Limit

c. FEBA Locations. Figures 7-11 and 7-12 display over a map at D+8 and D+20, respectively, the location of the historical FEBA, as calculated by ARCAS (solid dark line), the average of the 16 replications of the STOCEM base case (dashed dark line), and the average of the 16 replications of this STOCEM variation (white line). We observe from Figure 5-9 that German forces advance farther by D+8 in this variation than in the STOCEM base case, because of the higher rate of advance in breakthrough sectors in this STOCEM variation. The maximum D+8 penetration of this variation extends almost as far as in the historical Ardennes Campaign; the average D+8 FEBA location of this variation appears to agree best with history of all the STOCEM simulations of the Ardennes Campaign executed at CAA. By D+20, the US/UK forces in this STOCEM variation have retaken more terrain than in the STOCEM base case because of the high rate of advance in those sectors where counterattacking US/UK forces achieve the 6:1 combat worth ratio necessary for breakthrough.
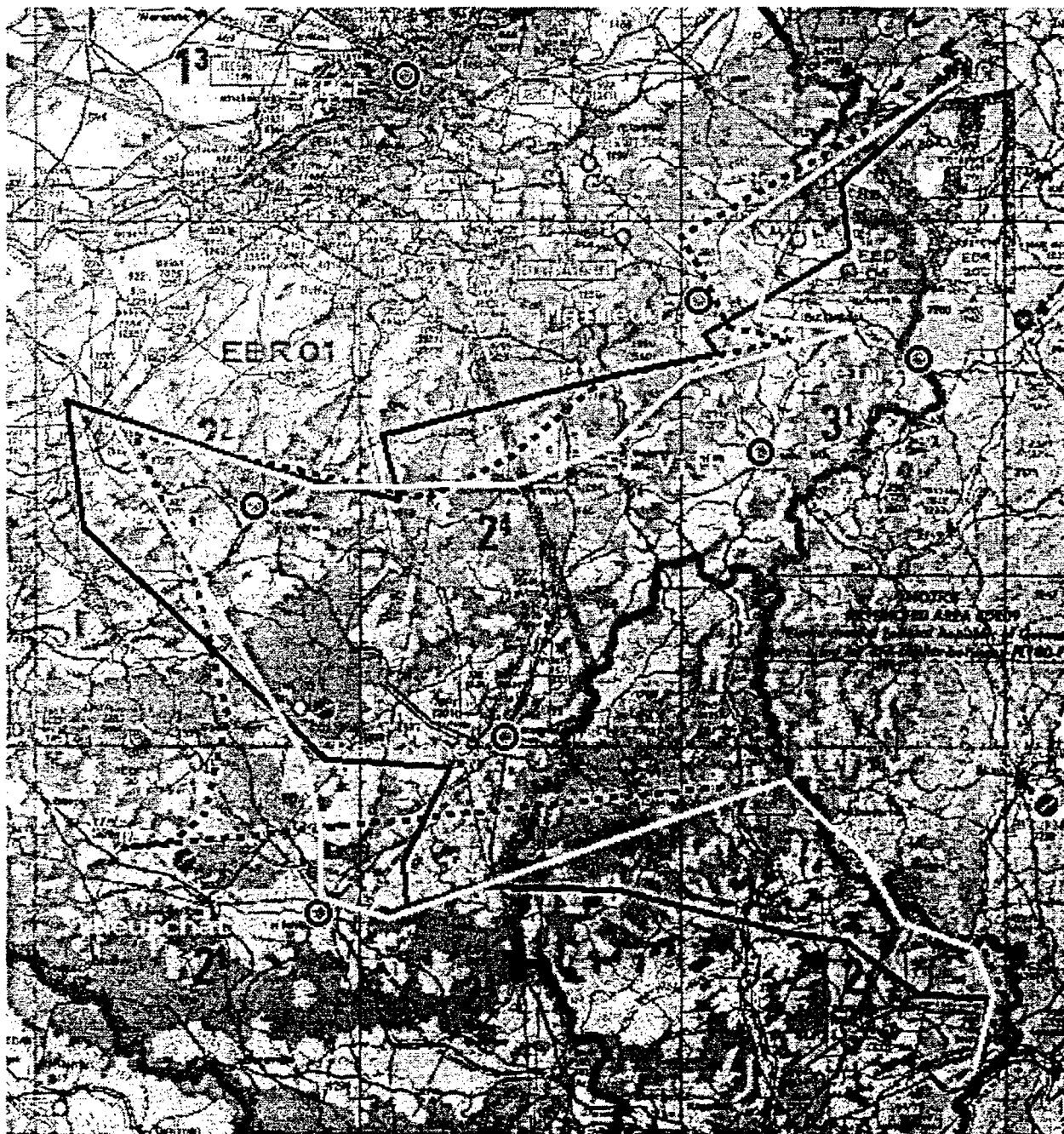
Figure 7-11. D+8 FEBA Locations: History, Base Case, and Breakthrough with 24-Hour Attack Limit
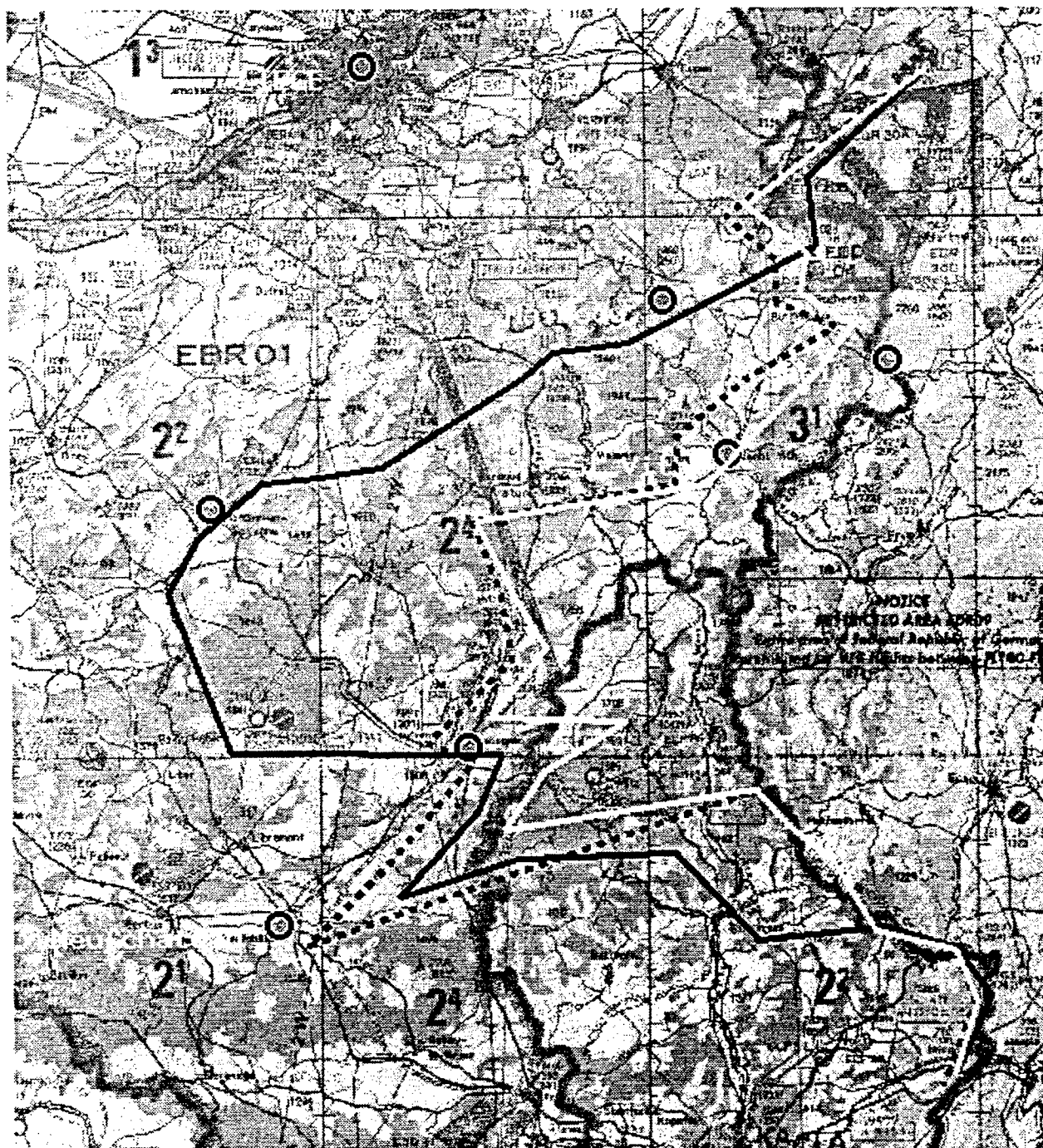
Figure 7-12. D+20 FEBA Locations: History, Base Case, and Breakthrough with 24-Hour Attack Limit

d. Personnel Losses. Figures 7-13 and 7-14 provide a comparison of the US/UK and German permanent personnel losses, respectively, among the historical results (bars), base case results (solid lines enclosing confidence intervals), and the results of this STOCEM variation (dashed lines enclosing confidence intervals). US/UK permanent personnel losses--dead, captured, missing, and patients requiring evacuation from theater--in this variation decrease slightly from the STOCEM base case due to decreased numbers of attacks permitted by the limit on consecutive attacks in this STOCEM variation. The same is true of German personnel losses in the first half of the simulation (Figure 7-14). German permanent personnel losses in this variation increased from the STOCEM base case in the second half of the simulated campaign. This confirms that counterattacking US/UK forces have sufficient strength in some sectors to satisfy the breakthrough criterion, thereby causing more German CMIA in those sectors than in the base case. The outcome makes the German casualties of this variation significantly further from the historical results than are those of the STOCEM base case.
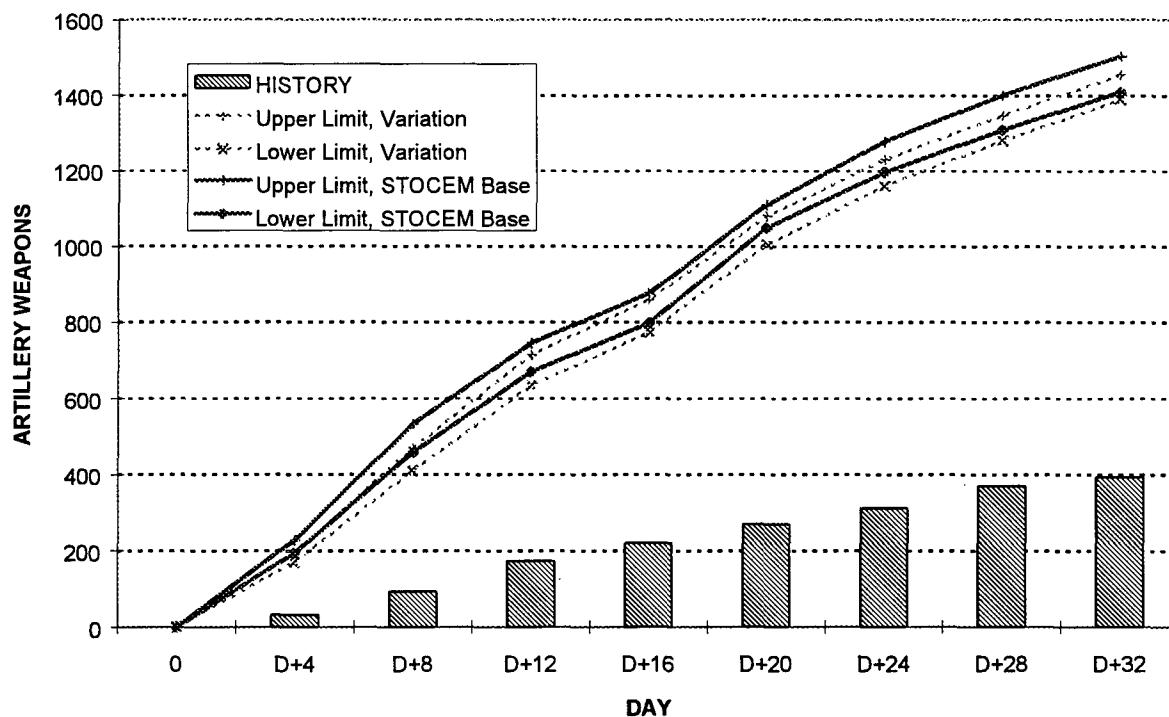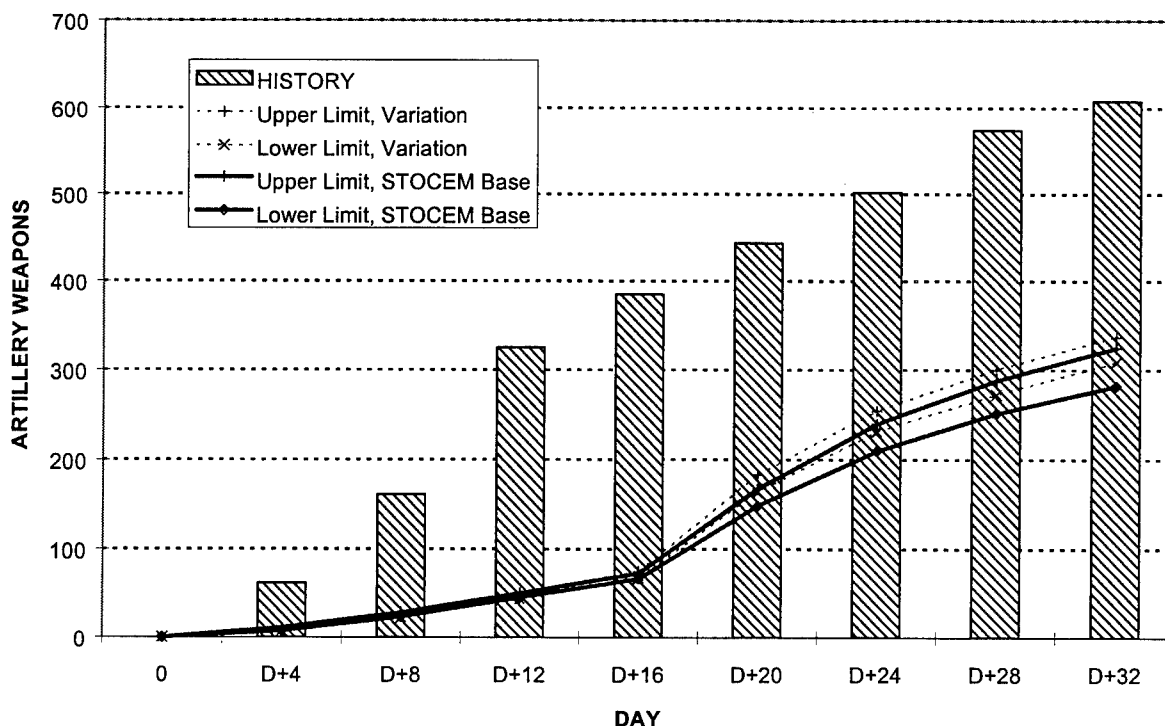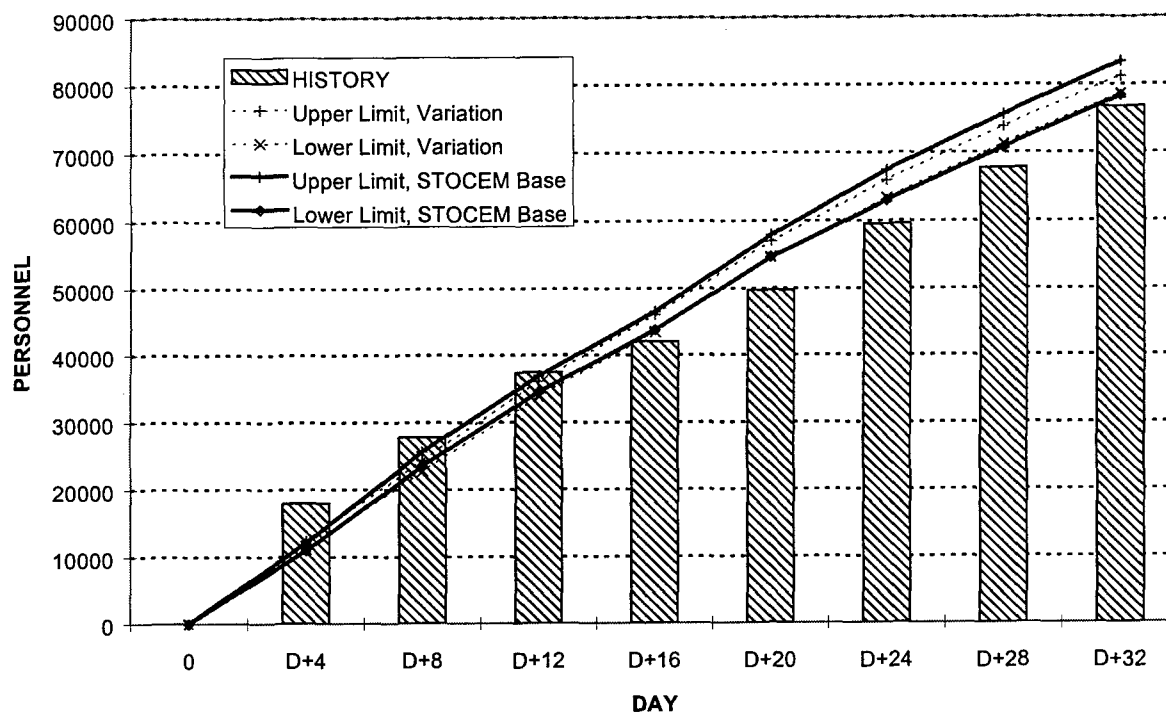

Figure 7-13. Cumulative Permanent Losses of US/UK Personnel, Breakthrough and 24-Hour Attack Limit
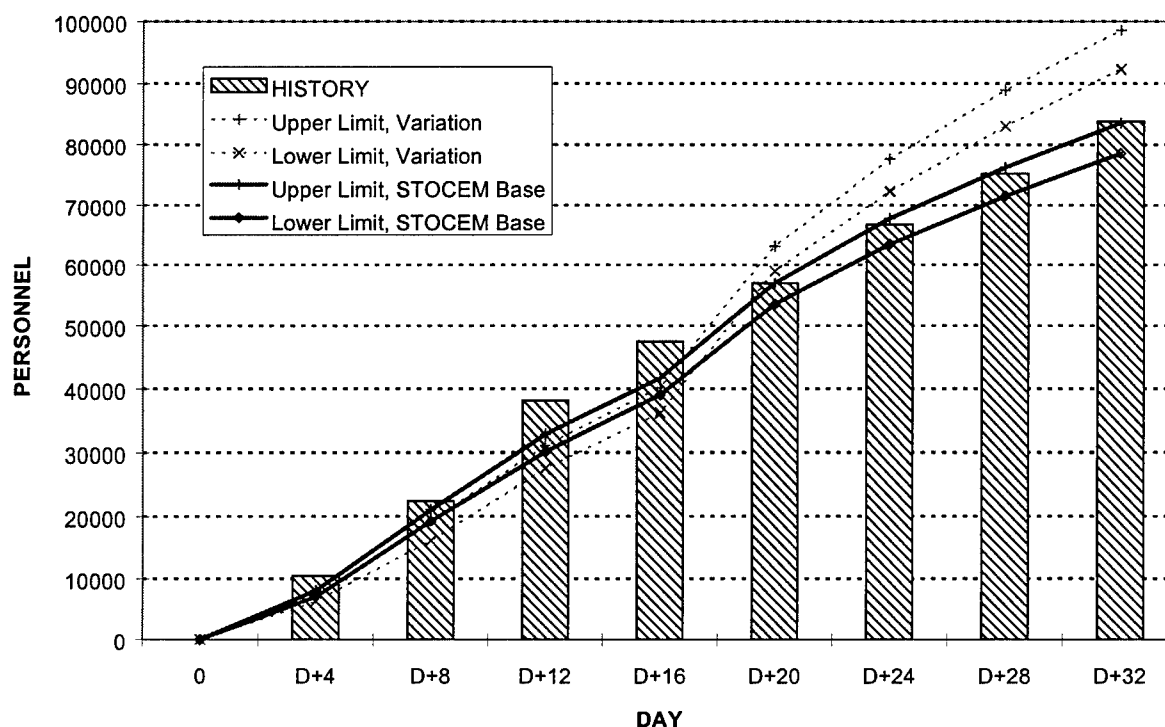
Figure 7-14. Cumulative Permanent Losses of German Personnel, Breakthrough and 24-Hour Attack Limit

e. US/UK Personnel Captured and Missing. Part of the ARCAS rationale for a STOCEM representation of breakthrough/overrun was that significantly smaller fractions of US/UK casualties in STOCEM were CMIA than in historical results. The STOCEM modeling of breakthrough/overrun in this variation causes greater numbers of CMIA among the defenders in the overrun sectors than in normal STOCEM attrition. Figure 7-15 provides a comparison of the fractions of daily US/UK casualties that are CMIA among the historical results (bars), base case results (solid lines enclosing confidence intervals), and the results of this STOCEM variation (dashed lines enclosing confidence intervals). As expected, the fraction captured or missing increased in the first 4 days of this variation from the STOCEM base case, due to the representation of breakthrough in this variation. However, the increase in CMIA does not extend beyond D+4 of this variation, and the CMIA fractions of this variation remain significantly smaller, throughout the simulation, than those of history.
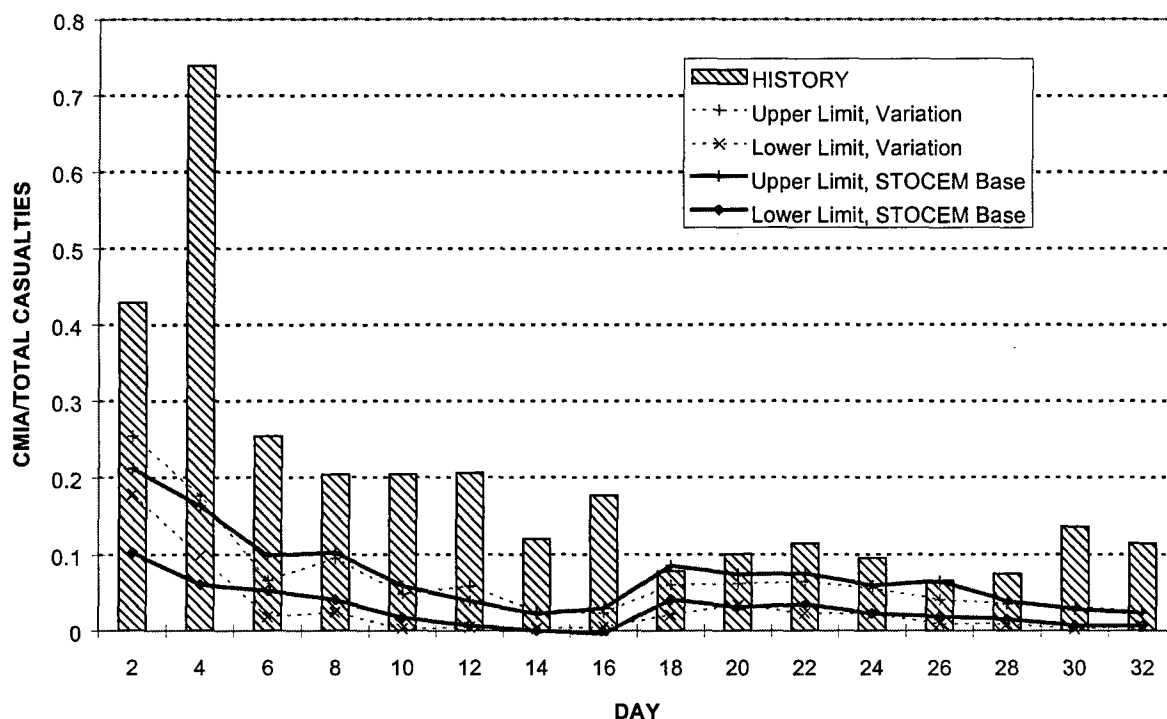
Figure 7-15. Fraction of US/UK Casualties that are Captured/Missing, Breakthrough and 24-Hour Attack Limit

f. Ammunition Consumption. Figures 7-16 and 7-17 provide a comparison of the US/UK and German cumulative ammunition consumption, respectively, among the historical results (bars), base case results (solid lines enclosing confidence intervals), and the results of this STOCEM variation (dashed lines enclosing confidence intervals). US/UK ammunition consumption (Figure 7-16) decreases slightly, and German ammunition consumption (Figure 7-17) decreases significantly, from the STOCEM base case because of the reduced quantity of attacks by each side permitted in this STOCEM variation. The German ammunition consumed in this variation agrees with history at D+4, but not thereafter.
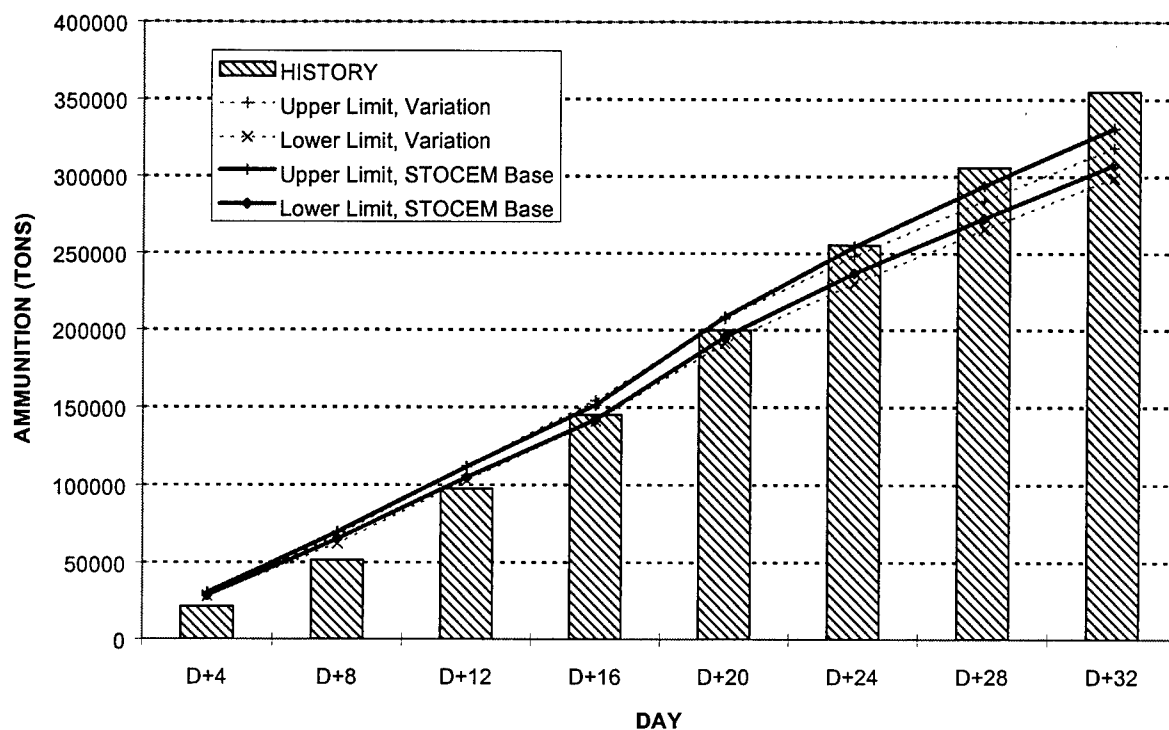
Figure 7-16. Cumulative Consumption of US/UK Ammunition, Breakthrough and 24-Hour Attack Limit
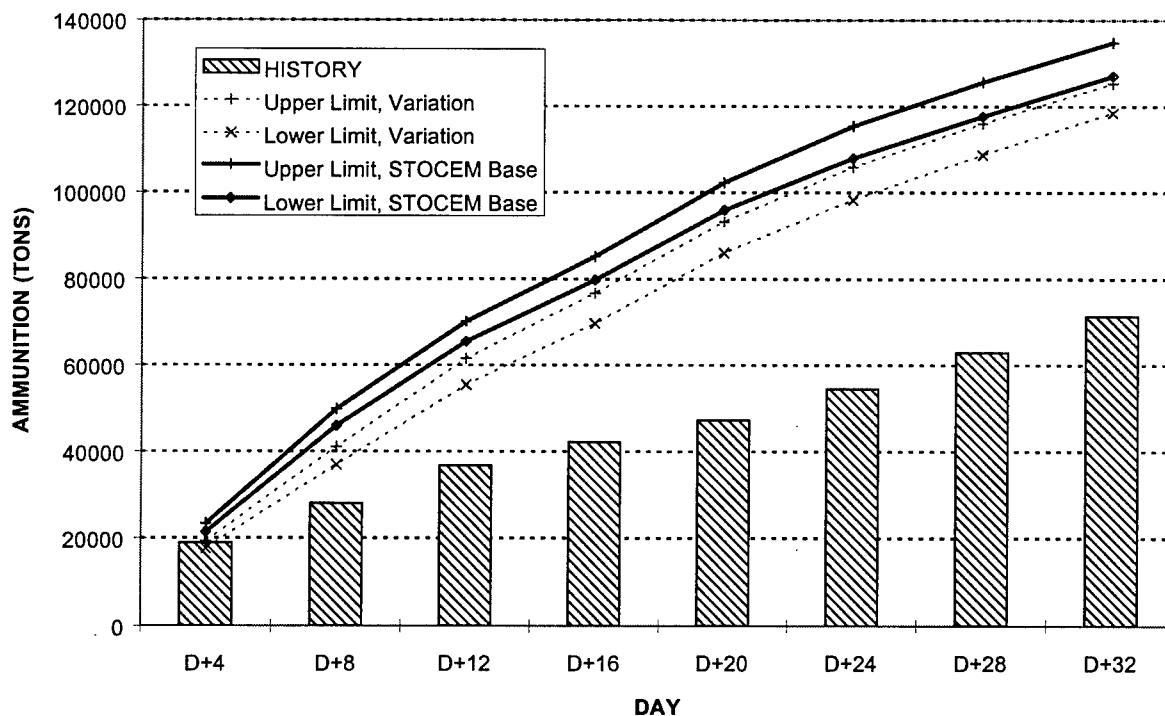
Figure 7-17. Cumulative Consumption of German Ammunition, Breakthrough and 24-Hour Attack Limit

7-4. OBSERVATIONS

a. The average D+8 FEBA location, resulting from the combined breakthrough/overrun and duration-of-attack enhancements of STOCEM, agrees better with history than does any previous STOCEM simulation.

b. The combined modifications of STOCEM decrease attrition of US/UK equipment and personnel from the STOCEM base case. US/UK losses generally decrease in this variation from the STOCEM base case because this variation permits a division to attack for only 24 hours at a time, so there are fewer divisions of both sides attacking in this variation than in the STOCEM base case. US/UK attrition results of these combined STOCEM modifications are significantly different from history for the preponderance of days reported.

c. The results of this chapter indicate that our combined modifications of STOCEM increase the attrition of German equipment and personnel in the second half of the campaign from the STOCEM base case. The increase in attrition of German equipment and personnel in this variation from the STOCEM base case, in the second half of the campaign indicates that counterattacking US/UK forces have sufficient strength in some sectors to satisfy the break-through criterion, thereby causing German units in those sectors to suffer greater permanent losses, including abandoned equipment and captured/missing personnel, in this variation than in the base case. German attrition results of these combined STOCEM modifications are significantly different from history for the preponderance of days reported.

d. In the results of the combined modifications of STOCEM the CMIA losses of US/UK personnel, as a fraction of total personnel casualties, are higher--and therefore closer to historical results--in the first 4 days than the CMIA of the STOCEM base case. The fractions of US/UK casualties that are KIA, WIA, CMIA, and DNBI with these combined STOCEM modifications remain significantly different from history for the preponderance of days reported.

e. The combined breakthrough/overrun and duration-of-attack enhancements of STOCEM cause consumption of ammunition by both sides to decrease from the base case because of the reduced quantities of attacks by each side permitted by the STOCEM 24-hour limit on the duration of attacks. Each side's ammunition consumption results of these combined STOCEM modifications are significantly different from history for the preponderance of days reported.

f. The combination of STOCEM improvements did not produce any noticeable anomalous results.

g. The ability of a STOCEM analyst to represent breakthrough and overrun by units with sufficient superiority in a sector while in the same simulation limiting the duration of attacks by units of one or both sides is a useful improvement to our campaign simulation capability, because it allows model users to represent situations that may realistically occur in combat. Making use of this greater flexibility in modeling will require analysts to assign values to the new STOCEM input parameters that control these features.

APPENDIX A

CONTRIBUTORS

A-1. TEAM

a. Director

Dr. Ralph Johnson, Operations Support Division

b. Team Member

Mr. William T. Allison

c. Contributor

Mr. Walter J. Bauman

A-2. PRODUCT REVIEW BOARD

Mr. Ronald J. Iekel, Chairman
Mr. Gerald E. Cooper
Dr. Robert L. Helmbold

APPENDIX B

REFERENCES

1. Ardennes Campaign Simulation (ARCAS), CAA-SR-95-8, US Army Concepts Analysis Agency, Bethesda, MD, December 1995

2. Stochastic Concepts Evaluation Model (STOCEM), CAA-TP-91-6, US Army Concepts Analysis Agency, Bethesda, MD, August 1991

3. Stochastic Concepts Evaluation Model - Phase II (STOCEM-Phase II), CAA-TP-92-2, US Army Concepts Analysis Agency, Bethesda, MD, June 1992

4. Stochastic Concepts Evaluation Model - Phase III (STOCEM-3), CAA-TP-93-2, US Army Concepts Analysis Agency, Bethesda, MD, June 1993

5. Concepts Evaluation Model IX (CEM IX), Volume II - User's Handbook, CAA-D-85-1, US Army Concepts Analysis Agency, Bethesda, MD, revised December 1995

6. Rates of Advance in Historical Land Combat Operations, CAA-RP-90-1, US Army Concepts Analysis Agency, Bethesda, MD, June 1990

7. CEM Research Project, CAA-SP-78-1, US Army Concepts Analysis Agency, Bethesda, MD, January 1978

APPENDIX C

REQUEST FOR ANALYTICAL SUPPORT

<table>
<tr>
<td rowspan="13" style="vertical-align:top">P
A
R
T

1</td>
<td colspan="4">REQUEST FOR ANALYTICAL SUPPORT</td>
</tr>
<tr>
<td colspan="2">1. Performing Directorate/ Division: OS</td>
<td colspan="2">2. Account Number: 96042</td>
</tr>
<tr>
<td colspan="2">3. Type Effort (Enter one):

Mode (Contract=C) [ ]   [R]

S   - Study
Q   - QRA
P   - Project
R   - RAA
M   - MMS</td>
<td colspan="2">4. Tasking (Enter one):

[I]

F   - Formal Directive
I   - Informal
V   - Verbal</td>
</tr>
<tr>
<td colspan="4">5. Title: Simulation Enhancements from Ardennes Campaign Ananysis</td>
</tr>
<tr>
<td>6. Acronym: SEACA</td>
<td>7. Date Request Received: 12/15/95</td>
<td colspan="2">8. Date Due: 05/31/96</td>
</tr>
<tr>
<td colspan="2">9. Requester/Sponsor (i.e., DCSOPS):   CAA</td>
<td colspan="2">10. Sponsor Division (i.e., SSW, N/A)   N/A</td>
</tr>
<tr>
<td colspan="4">11. Impact on Other Studies, QRA, Projects, RAA: N/A</td>
</tr>
<tr>
<td colspan="4">12. Product Required: Report</td>
</tr>
<tr>
<td colspan="2">13. Estimated Resources Required:</td>
<td>a. Estimated PSM: 4.5</td>
<td>b. Estimated Funds:</td>
</tr>
<tr>
<td colspan="3">c. Models Req'd: CEM, STOCEM</td>
<td>d. Other:</td>
</tr>
<tr>
<td colspan="4">14. Objective(s)/Abstract:
To investigate the potential enhancements to the Concepts Evaluation Model (CEM) suggested by the results of the Ardennes Campaign analyses conducted by CAA. To determine a suitable logic for such enhancements, to implement and test the enhancements, and to compare the enhanced simulation results with results of the Ardennes Campaign analyses.</td>
</tr>
<tr>
<td colspan="2">15. Study Director/POC:</td>
<td>Last Name: Johnson   First: Ralph</td>
<td>Date: 12/15/95</td>
</tr>
<tr>
<td colspan="2"></td>
<td>Signature: <i>Ralph Johnson</i></td>
<td>Phone#: 295-1542</td>
</tr>
</table>

GO TO BLOCK 20 *If this is A STUDY.* See Tab C of the Study Directors' Guide for preparation of a Formal Study Directive.

<table>
<tr>
<td rowspan="7" style="vertical-align:top">P
A
R
T

2</td>
<td colspan="3">16. Background/Statement of Problem*: The Ardennes Campaign Follow-On analysis, completed in December, 1995, suggested modifications to CEM/STOCEM that should bring simulation results into closer agreement with historical results of the 1944 Ardennes Campaign.</td>
</tr>
<tr>
<td colspan="3">17. Scope of Work*: Suggested modifications to CEM/STOCEM include a means of representing the effects of a breakthrough of enemy lines by an attacking force; a limit on the duration of a sustained attack; and a different way of distributing personnel casualties among killed, captured, missing, wounded, and disease/nonbattle-injured.</td>
</tr>
<tr>
<td colspan="3">18. Issues for Analysis*: What is an appropriate methodology for improvement of CEM/STOCEM? How do the results of the enhanced STOCEM compare with Ardennes Campaign historical results? How do the results of the enhanced STOCEM compare with previous STOCEM simulation results?</td>
</tr>
<tr>
<td colspan="3">19. Milestones/Plan of Action*: Analysis Review Board: Feb 96, May 96. PRB 28 May 96</td>
</tr>
<tr>
<td>20. Division Chief Concurrence: <i>WWC</i></td>
<td>Wallace W. Chandler, Chief RSO</td>
<td>Date: 10/3/96</td>
</tr>
<tr>
<td>21. Sponsor (COL/DA Div Chief) Concurrence:</td>
<td></td>
<td>Date:</td>
</tr>
<tr>
<td colspan="3">22. Sponsor Comments*:</td>
</tr>
</table>

CAA Form 233 (1 May 95)   * Continue on separate sheet   Previous editions Obsolete

APPENDIX D

STOCEM SIMULATION RESULTS

Table D-1 summarizes the STOCEM results presented in this report, subjectively compared to the historical results of the Ardennes Campaign.

Table D-1. STOCEM Simulation Results

STOCEM case	0	1a	1b	2	3	4
Chapter or paragraph	3	4-2	4-3	5	6	7
Limit on attacks						
(hours, B/R)	No limit	24/24	12/192	No limit	No limit	24/24
Breakthrough/Overrun	No	No	No	Yes	No	Yes
DNBI & CMIA Increased	No	No	No	No	Yes	No
FEBA Location	OK	SL	OK	OK	OK	OK
Blue Personnel Losses	OK	SL	OK	OK	SH	OK
Red Personnel Losses	OK	SL	OK	AH	OK	SH
Blue Tank Losses	SH	SH	SH	AH	SH	SH
Red Tank Losses	AH	AH	AH	AH	AH	AH
Blue Artillery Losses	VL	VL	VL	VL	VL	VL
Red Artillery Losses	VL	VL	VL	AL	VL	VL
Blue Light Armor Losses	VH	AH	VH	VH	VH	VH
Red Light Armor Losses	SH	SH	SH	AH	SH	AH
Blue Antitank/Mortar Losses	VH	VH	VH	VH	VH	VH
Red Antitank/Mortar Losses	VH	VH	VH	VH	VH	VH
Blue Ammo Consumed	OK	OK	OK	SL	OK	OK
Red Ammo Consumed	VH	AH	VH	VH	VH	AH
Blue KIA Fraction	AH	AH	AH	AH	SH	AH
Blue WIA Fraction	VH	VH	VH	AH	AH	AH
Blue CMIA Fraction	AL	AL	AL	SL	SL	AL
Blue DNBI Fraction	VL	VL	VL	VL	AL	VL

Notes:
Case 0 = STOCEM base
VL = STOCEM is much lower than history
AL = STOCEM appreciably lower than history
SL = STOCEM slightly lower than history
OK = STOCEM generally agrees with history
SH = STOCEM slightly higher than history
AH = STOCEM appreciably higher than history
VH = STOCEM is much higher than history